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PRACTICAL ENGINEERING DRAWING

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PRACTICAL ENGINEERING DRAWING

A text-book for students for the First Year National Certificate in Engineering

by

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THE ENGLISH UNIVERSITIES PRESS LTD.
LONDON

First Printed . . . . . . August 1944

This book is produced in complete conformity with the Authorized Economy Standards

Made and Printed in Great Britain by Hazell, Watson & Viney, Ltd., London and Aylesbury.

GENERAL EDITOR'S FOREWORD

TECHNICAL education stands on the verge of a great advance, probably the greatest in its history. Throughout the country there is general recognition of the necessity for a great expansion of the facilities which are available for thorough and systematic training for science and industry. This desire finds expression in the provision which has been made in the new Education Act for all forms of technical education. During the war many thousands of men and women have been compelled to undergo brief and hastily improvised courses in scientific and technical processes, and this has helped to bring home to them, and to most people, the importance of systematic technical education in the conditions of modern life.

There is general recognition of the well-founded conclusions of experts that the economic prosperity of this country will, more than ever before, be dependent upon the efficiency and adaptability of our system of scientific and technical training.

It is the hope and ambition of those who have planned this series of technical books, that it will meet the demands for new books which will follow these developments. New measures require new books, and it is hoped that this series will not only assist in meeting these requirements, but will incorporate those new methods and processes which have been introduced during the war years.

Fundamentally the books of the series are based, whenever this is necessary, on the Course system, which is now an established feature of technical education. Accordingly, in basic subjects, there will be suitable volumes for the successive years of the Course. It is recognised that there must be differences of opinion among teachers as to the sequence and contents of the work in the different years of a Course. But in general it is hoped that the treatment of the subjects will be sufficiently flexible to meet the needs of most teachers and students.

P. ABBOTT.

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A DROP STAMP

(See Chapter X, fig. 144)

PREFACE

(Both student and teacher should read this.)

An effort has been made in preparing this book to provide a text-book with which a student, given the supplementary guidance of the teacher, may commence with the simple but essential materials of the general engineering workshop, and whilst considering the elementary methods of draughtsmanship, may gain a wider experience of engineering practice than is possible in any particular industrial undertaking. Obviously it will be necessary to enlarge on any special aspect, since it is only possible to present the preliminary principles. It is hoped that a student, using the book intelligently under able supervision, will be able to produce workshop drawings in conformity with modern practice, and will be able to visualise the more readily the drawings used in his particular work.

It is appreciated that the exercises set toward the end of the book are difficult, but with preliminary explanation and assistance, the student should be able to prepare some very interesting and pleasing specimens of his workmanship. For the teacher, the exercises have been grouped into sets based on the preceding work, and in the earlier exercises the space occupied is given as a guide in planning a set of classwork.

It is hoped that the text will be read. All the text is complementary to the drawings, and is a guide to the exercise following.

The work has been designed to present modern practice in a variety of industries, and in this connection thanks are due to numerous firms who have supplied drawings and photographs.

Finally, thanks are due to the British Standards Institution for permission to reproduce tables and data from their specifications. The recommendations of the committee on drawing-office practice have been followed as far as possible throughout the book.

English orthographic projection has been used exclusively, since many firms and most examining bodies adhere to this practice. It is hoped in a succeeding work to introduce the very useful American or Third-angle projection.

Note.—All the drawings throughout this book were prepared before the issue of the new Specification on Drawing Office Practice (B.S. No. 308, 1943). In one respect they do not conform to the requirements of the specification, viz. the limiting lines for dimensions are carried right up to the outline of the drawing instead of allowing a small break as now required. Fig. 88 only has been corrected to the new specification.

FOREWORD

In the dawn of civilisation men began to convey their thoughts by means of pictures. With the increasing complication of life, the need for pictorial representation of new ideas became more evident, and so, at the commencement of the machine age, men began to realise the need for technical education to supplement their craftsmanship. In order that new ideas and processes might be explained and used, a thorough understanding of working drawings was necessary. Thus, from the beginning, the importance of engineering drawing has been recognised in technical education. An engineer must be able to make a drawing which is clear to everybody concerned, and he must be able to read a drawing, however complicated, quickly and accurately.

An artist can make a picture to convey an idea, but when a complex mechanism or structure is to be made, it is necessary to show some representation in which every particular of the construction and size is apparent. Pictorial representation is not convenient for this purpose, and therefore drawings of machine parts, etc., are made according to a simple, acceptable principle known as orthographic projection. From such drawings, every detail, small or large, can be made and assembled precisely. It will be obvious that in the actual making and reading of the drawing itself, great accuracy and care is essential, and the purpose of the machine drawing class is to instil the principles of accuracy and neatness in drawing, so that whether the student engages on design or production, he will be well equipped to convey his thoughts and to read other people's thoughts for the purpose of increasing the general efficiency.

A good drawing must be accurate, and a good drawing must be neat. The student must develop both these traits from the commencement of his work, even on the simplest exercise, then, as the work becomes more involved, his accurate, neat workmanship will be pleasing, valuable and instructive.

Engineering drawing is a subject which is never completely learnt; there are so many auxiliary subjects, processes and practices, that the most skilful draughtsman or engineer has always more to learn. It is the purpose of this book to direct the eyes and comprehension of the student to the salient features of some of the many branches of engineering drawing; the student must supplement his classwork by intelligent observation in the workshop and elsewhere.

Chapters I to V may be considered as a foundation. Having mastered those fundamentals, the principles may be developed in the practical work of Chapters VI to XI. Finally, with an introduction to a few of the production processes pursued outside the general machine shop, the student can study and work on the typical drawings grouped in Chapter XII.

CONTENTS

Chapter I

DRAWING MATERIALS AND INSTRUMENTS

"Give us the tools and we will finish the job."—THE PRIME MINISTER, THE RT. HON. WINSTON CHURCHILL, 1941.

QUALITY

THE importance of using good quality equipment in every sphere of life is well recognised. The student should therefore seek to obtain the best instruments possible, and take a pride in his equipment and work.

DRAWING MATERIAL

In practice, a drawing is the first definite step towards production, but, as explained later in Chapter VI, there are also stages toward the final detailed drawing, and each requires a different type of paper. Finished working drawings are made on sheets of paper ruled out to a standard size for convenience and uniformity, the sizes of the sheets being based on the following:

Antiquarian	53 in. × 31 in.
Double Elephant ..	40 in. × 27 in.
Imperial	30 in. × 22 in.
Half Imperial	22 in. × 15 in.

Subdivisions made to approximately 15 in. × 11 in. and 11 in. × $7\frac{1}{2}$ in.

Drawing boards are also made to suit these sizes, the boards being an inch or two larger each way for the four named sizes. In addition, in drawing offices, larger boards 80 in. × 53 in. are sometimes used.

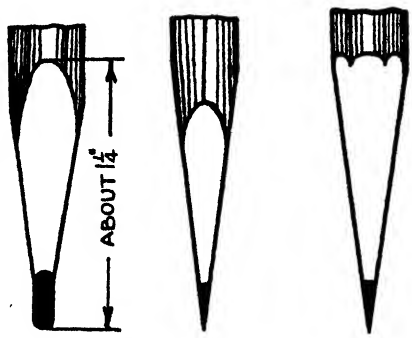
Paper. Before the final working drawings can be made for any device, drawings must be prepared carefully to check the practicability of the idea, both from the point of view of its functioning and of its convenient manufacture. These are usually done on cartridge paper, which is good quality stout paper having a smooth surface, similar to the sheets used in drawing classes. On approval of the design, final working drawings of details and assemblies may be made. For this, a thin, smooth, transparent paper known as tracing paper is used. From drawings made on this paper direct copies may be made by a photographic process to give "prints," which are issued to the departments and workshops concerned. Since the most common and simple process is the ferro-prussiate, which gives white lines on a blue background, the prints are usually known as blue-prints.

Tracing paper is very flimsy, and after a time becomes brittle, so that drawings in use get badly torn. Therefore, when a successful experimental model has been made, the drawings are made more permanent by tracing them on to a sheet of linen using black Indian ink. From ink drawings, prints may be prepared giving a black or brown line on a white background. Alternatively, the drawings are inked in on a slightly stiffer translucent paper known as detail paper, and the edges bound with adhesive tape. Tracing paper and linen is often prepared, made up into the standard sizes and printed with the firm's name, etc., as in fig. 86, Chapter VI.

There are one or two newer processes by which the original pencil drawings may be either photographed or "fixed" (*i.e.*, made permanent), but the practice of printing as outlined above is, at the moment, the most general.

Pencils. For various grades of paper, pencils are made in degrees of hardness, varying from 9H the hardest to H; then F or HB medium grade to the softer B pencils, down to 6B. In the drawing office 1H to 3H are used generally, and

4H or 6H for fine layout work on cartridge paper. Students should obtain a good make of 2H and 3H pencil for the drawing class, or otherwise as advised by the teacher to suit the grade of paper used. To draw good, clear, firm lines, the 3H should be sharpened to a chisel edge as shown in fig. 1, by using a knife and finishing the lead on a smooth file or glasspaper block. The edge, prepared in this manner, wears better and makes cleaner lines.



3H FIG. 1 2H
CHISEL POINT CONE POINT

Note. *Always sharpen the end remote from the pencil grade number, so that the marks 3H, etc., remain on the uncut end.*

The 2H is used for lettering and any freehand sketching work, and it is sharpened well back to a conical point.

Boards. The best boards are made of well-seasoned wood, with grooves, battens, and slotted fixing holes, designed to prevent warping. In the left-hand shorter edge a slip of hard ebony is inserted, to provide a true and more permanent guide for the tee square.

Tee Squares. When using a tee square make sure that the stock is kept well up to the edge of the board, and remember that the tee square stock slides up and down the left-hand short side of the board only. The tee square is used for drawing horizontal lines, but be careful that the chisel edge of the pencil is kept well up against the blade of the square, not inclined away from it. (See fig. 2.)

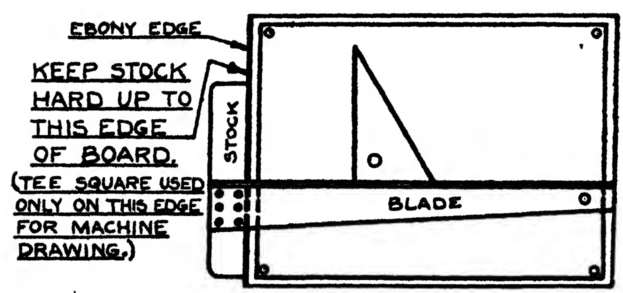
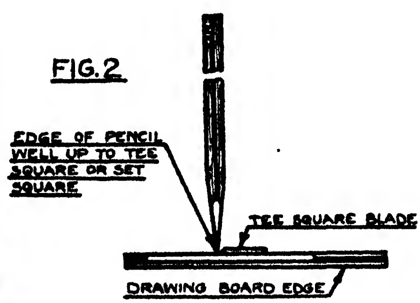


FIG. 2



Cleaning. Before using tee squares or set squares, thoroughly clean them with a duster. After some use, the squares, in rubbing over the pencil lines, get very dirty by picking up the graphite dust, and then are most effectively cleaned by rubbing them with, or on, a sheet of scrap paper.

Set Squares. Two set squares are required, a 45° and 60°, and good stout celluloid squares should be obtained. A 60° square is measured by the length of the longer side forming the right angle, and a 45° square by the length of either side of the right angle. (Except an adjustable square, which is measured by the length of the adjustable arm.) Make sure that the square is held hard up against the blade of the tee square, and the pencil up to the edge of the square. Perpendicular lines, or parallel lines at 30°, 45° or 60° to the vertical, are drawn with tee squares and set squares. By using two squares, angles of 15° or 75° (30° + 45°) may be drawn.

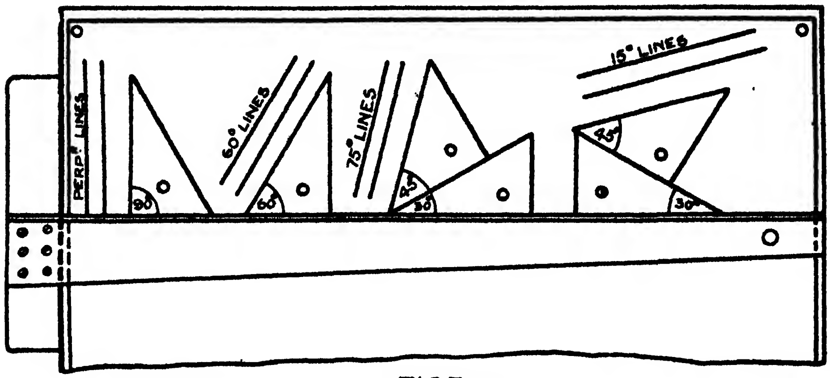
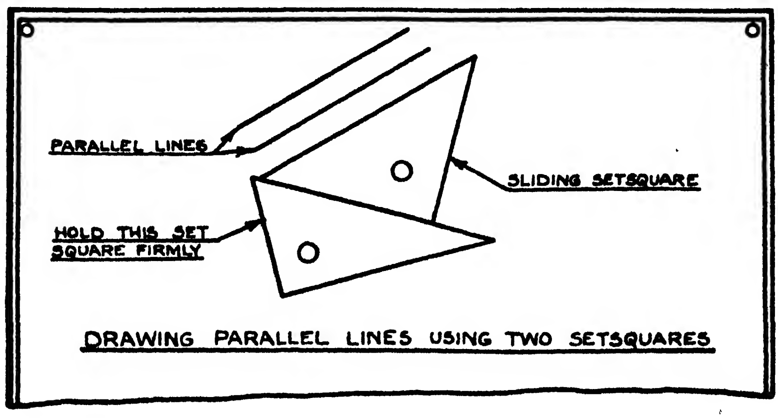


FIG.3



DRAWING PARALLEL LINES USING TWO SETSQUARES

Set squares are also used for drawing parallel lines at any angle by sliding one along the edge of the other (fig. 3).

Compasses. It is important that good quality compasses, of rigid construction, having legs about 6 in. long with a separate needle point and fitting for the pencil lead, should be used (fig. 4). The needle point should be shouldered as shown to avoid making a large hole with the point when drawing several concentric circles.

Springbows. Small compasses, with the legs controlled by a spring and set by a screw and nut, are essential for accuracy in drawing small circles. These also should be of rigid construction and have a separate shouldered needle point.

The lines drawn with the compasses should be of the same density as those drawn with the pencil, but it is difficult to exert the same pressure on a compass lead, and it is therefore desirable to use a slightly softer lead in compasses, say a 2H. Leads may be taken from short ends of pencils.

The lead for compasses and springbows should be adjusted in length to be between the needle point and shoulder, and the chisel edge should be finished with the lead in position. (See fig. 5.) In preparing the chisel edge, it must be remembered that a wide edge will not give a sharp line owing to the tangential position of the edge. The chisel edge, therefore, should be prepared as shown.

For very large circles, either an extension bar for the compasses, or a beam compass is used, but it is not usually necessary to have these in a

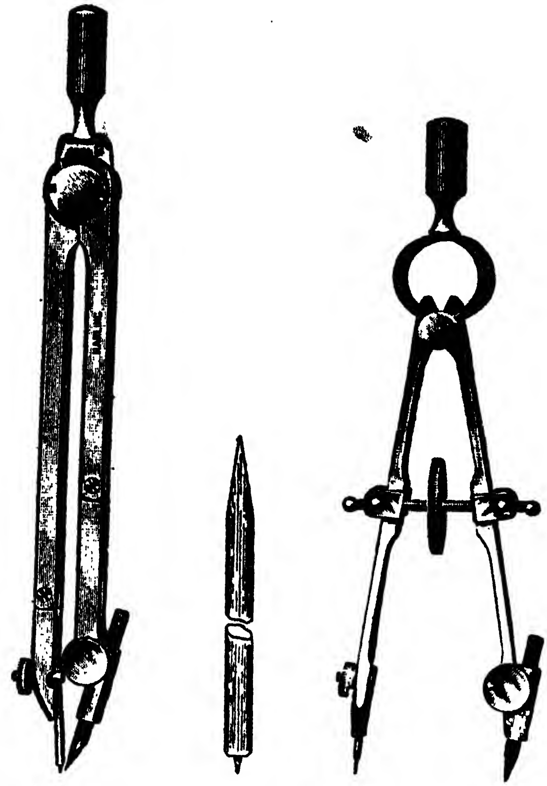


FIG. 4.

(*Fig. 4 by permission of Messrs. W. H. Harling, Ltd.*)

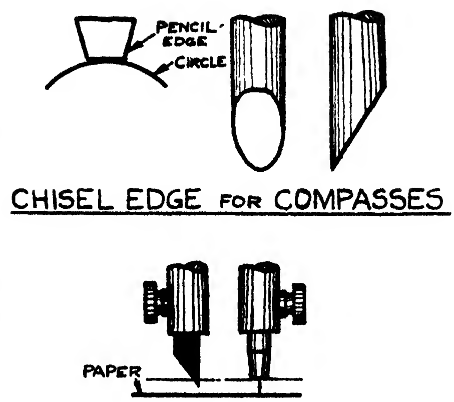


FIG. 5

first year class. It is strongly recommended that good quality instruments are obtained at the first, as they are invaluable throughout the period of technical study, and in most technical branches of industry.

Rule, Protractor, etc. The student will need a rule, a protractor, drawing pins and a rubber. It is difficult to obtain a satisfactory rule for mechanical engineering drawing, and in practice many draughtsmen use a steel rule. A foot rule should be used, divided into $\frac{1}{8}$ in., $\frac{1}{16}$ in. and $\frac{1}{32}$ in., and it should be thin or bevelled to a thin edge, so that the graduations are close to the paper. Boxwood rules are easily read, but most of these are graduated in twelfths or fractions of twelfths of an inch, and are therefore not suitable for mechanical work generally. A very satisfactory, though rather expensive rule, is one having ivorine faces on boxwood, with a stiffening core as shown. The four edges may be divided into $\frac{1}{32}$ in., $\frac{1}{50}$ in., millimetre and half-scale (fig. 6). The construction and use of scales is discussed in Chapter II, page 12. A semicircular or circular celluloid protractor of about 3 in. radius is most suitable, though the boxwood rectangular type is satisfactory for students' work.

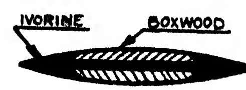


FIG. 6

For tracing with Indian ink, special ruling pens, compass fittings and spring-bows are required, but the student will not need these for class work.

Dividers, which always appear in the

artistic conception of an engineer, are of little practical use. The students' requirements, therefore, are as follows :

- Board and tee square—usually half imperial and generally supplied in class.
- Set squares—preferably stout celluloid —60°, 8–10 in. ; 45°, 8 in.
- Compasses—6 in. with detachable needle.
- Pencil springbow—3 in.
- Rule—12 in. divided into $\frac{1}{8}$ in., $\frac{1}{16}$ in. and $\frac{1}{10}$ in., and millimetres.
- Pencils—3H and 2H, good quality.
- Rubber—soft. Drawing pins.
- Protractor—preferably semicircular celluloid, 6 in. diameter.
- An erasing shield is also useful but not essential.
- A small smooth file or sandpaper block for sharpening leads.
- A duster for cleaning squares.

Note. *Avoid the bad habit of wiping hand or duster over the drawing ; it makes the work dirty and smudgy.*

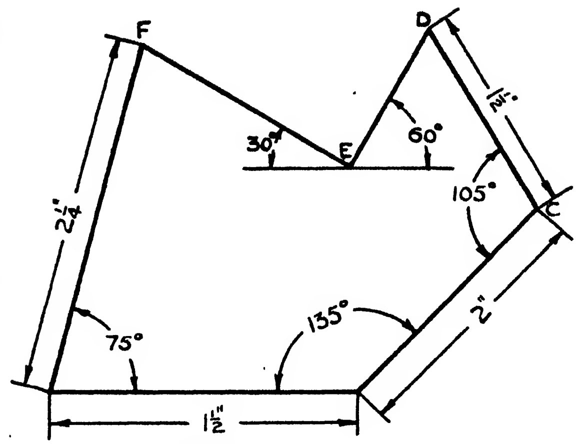


FIG. 7
(NOT TO SCALE)

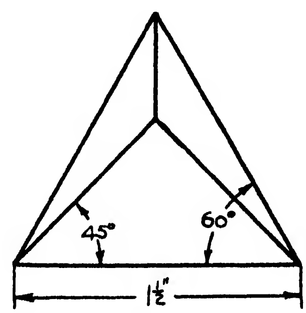


FIG 8

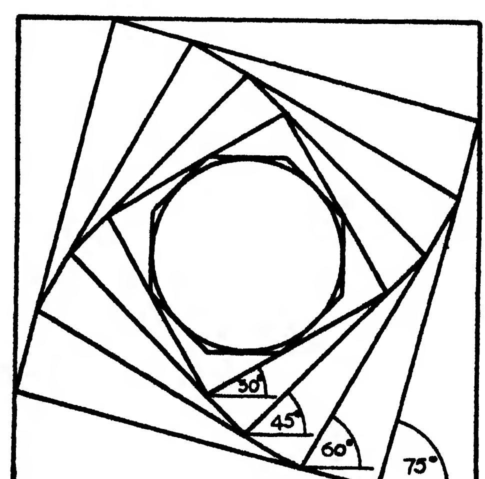


FIG. 9

EXERCISE I

(1) Draw circle 1¾ in. diameter. Using a tee square and 60° set square, draw a regular hexagon, each side to touch the circle. Draw three lines parallel to and ¼ in. from one horizontal and two sloping sides to form an equilateral triangle. Measure each side.

(2) Draw circle 1¾ in. diameter and draw a regular octagon as in question 1, using a 45° set square. Draw a line passing through two opposite corners and mark off with springbows ¼ in. outside the corners. Through these points, using a 45° set square, draw lines parallel to the sides of octagon to make a square. Measure the four sides and the other diagonal.

(3) Copy fig. 7. Measure sides FE and DE, and angles at F and D. (Note figure is not shown to scale.)

(4) Draw line 1½ in. long and from each end draw lines 1½ in. long each sloping outwards at an angle of 108°. From the ends of these lines draw two more lines 1½ in. long to make a closed figure. Measure from ends of first line to final point, and across ends of the first two inclined lines. Compare these lengths.

(5) Draw line 1½ in. long as the common base of two isosceles triangles on same side of the line, having angles of 60° and 45° at base. Find the mid point on a line joining the two top points (by trial), and with this as centre, draw a circle to pass through the ends of the base (fig. 8). Set compasses to 1½ in. and step round the circle from one end of the base to mark off a regular pentagon. (Note.—This construction is not precisely accurate mathematically, but the inaccuracy is exceedingly small.)

(6) Draw a regular octagon outside a 1½ in. diameter circle, and copy fig. 9. Measure each side and diagonal of the final square.

ACCURACY AND NEATNESS

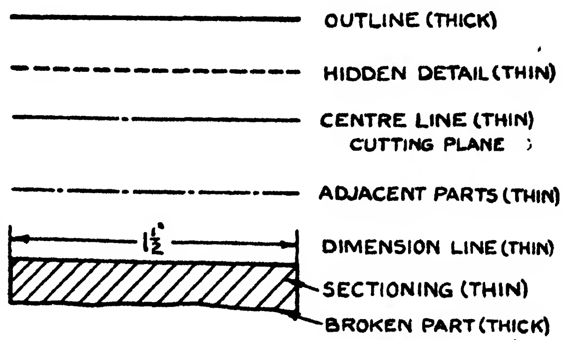
Developed by

PLANE GEOMETRY

"There is no discipline which so readily tests error . . . as drawing properly taught."—PROF. HUXLEY, 1887.

NEAT workmanship is essential to an engineer. Whether making a freehand drawing or a finished working drawing, accuracy is aided by neatness and legibility. A machine drawing is not a work of art, but successful production of any article will be more certain if the machine drawing is clear, well set out, complete, and in accordance with standard practice.

On a finished machine drawing, lines must be boldly and crisply drawn with a well-sharpened pencil, but any constructional work must be very faint and unobtrusive. The types of lines used in machine drawing are shown in fig. 10. Reference is made to the use of these lines in Chapters III, IV and VI. Freehand work is rarely permissible on a machine drawing.



TYPES OF LINES

FIG. 10

LETTERING

Lettering must be neat, bold and consistent, simplicity of style, rather than art, being the essential. Practise various sizes of lettering, making the characters of a round formation and to appear of uniform width. The spacing of characters and words is important.

Block capitals should be used always for a machine drawing. The letters used for titles will vary in height from about $\frac{1}{2}$ in. to $\frac{1}{4}$ in., and the various notes will be in letters about $\frac{3}{32}$ in. high. It is advisable to draw faint guide lines for any lettering, and to keep letters just touching the upper and lower line. All letters used in any title or note must be of the same height; it is not generally desirable to make the first letter larger than the succeeding characters. Study the letters and figures shown in fig. 11, and avoid slovenly schoolboy types of characters.

ABCDEFGHIJKLMNOPQRSTUVWXYZ

123456789 $2\frac{1}{2}$ $3\frac{3}{4}$ $4\frac{7}{8}$ $1\frac{1}{16}$ NOT $1^1/_{16}$

FIG. 11

The figures on any drawing are vital; an indistinct or erroneous figure may cost hours of time and much money. Time is well spent in practising to develop a clear, simple, bold style of figure, as in fig. 11. Note that the figures should never be less than $\frac{3}{16}$ in. to $\frac{1}{8}$ in. high, and the line between numerator and denominator of a fraction must always be horizontal. This is to avoid the possibility of error due to untidy work, as illustrated in fig. 11 by the dimension $1\frac{1}{16}$ in. which may easily be read as $\frac{11}{16}$ in.

EXERCISE II

(1) Make a neat alphabet in $\frac{1}{4}$ in. characters evenly spaced, and numerals 0–9 in $\frac{3}{16}$ in. characters.

(2) Print the following in neat characters in the following sizes:

- (*a*) "Lettering must be bold and broad"—in $\frac{1}{4}$ in. letters.
- (*b*) "Three holes to be drilled $\frac{3}{4}$ in. deep and tapped $\frac{3}{8}$ in. B.S.F. $\frac{1}{2}$ in. deep"—in $\frac{1}{8}$ in. letters.
- (*c*) "The line between figures of a fraction must be horizontal"—in $\frac{3}{16}$ in. letters.
- (*d*) "Keep your tee square stock to the left-hand edge of board only"—in $\frac{3}{32}$ in. letters.

(3) Print the title block shown in fig. 12*a*, using characters stated. Make the layout of block as symmetrical as possible.

(4) Print the schedule shown in fig. 12*b* using characters stated.

(5) Copy material list fig. 12*c*.

GEOMETRICAL CONSTRUCTIONS

The need for accurate workmanship has already been stressed, and in the following exercises, whilst getting accustomed to the use of the instruments, the student should strive to make his work both accurate and neat.

Construction I

Parallel lines. The use of set squares and tee squares for drawing parallel lines has been shown, but sometimes it is convenient to use compasses for the purpose. With the compasses set at the spacing of the required parallel line, describe two arcs on the same side, one from each end of the given line. A line drawn to just touch both arcs will be parallel to the given line. (A line touching an arc or circle is called a tangent to the arc.) (Fig. 13*a*.)

Construction II

Perpendicular bisector. A set square provides the simplest way of drawing a line perpendicular to another, but a line can be very accurately divided into two equal parts (*i.e.*, bisected) by a perpendicular line by the use of compasses and a straight edge. With a radius greater than half the line, describe arcs on each side from the extreme ends of the line. Draw a straight line through the intersection of each pair of arcs, and this line will pass through the centre of the given line, and will be at right angles to it. This construction is used very often (fig. 13*b*).

(Note that this construction can be applied to bisect a length of arc between two given points on the arc.)

Application I. To find the centre from which a circle or a circular arc has been described. Draw any two chords (they must not be parallel) and perpendicularly bisect each one. The perpendiculars will intersect at the required centre (fig. 13*c*).

Application II. To draw a circle to touch each corner of a triangle, *i.e.*, a circumscribing circle. The perpendicular bisectors of the three sides will all meet at one point—the centre of the circumscribing circle (fig. 13*d*).

Construction III

Equal division of a line. To divide a line of any given length into any given number of equal parts without measurement.

For example, to divide line AB, fig. 14 (length unknown) into, say, seven equal parts, draw from A a line inclined at a convenient angle. Along this line, step off seven equal spaces of a convenient length, with compasses or spring-bows, and join the last point 7 to the end B of the given line. From points

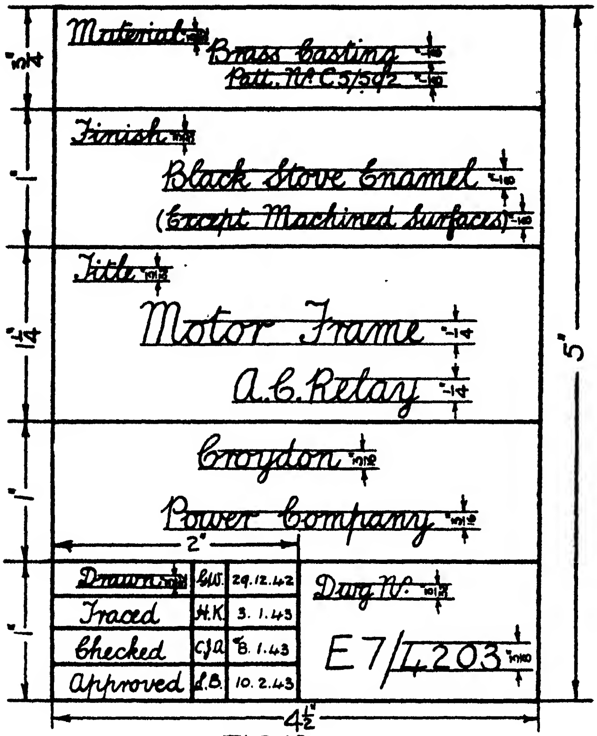


FIG. 12a

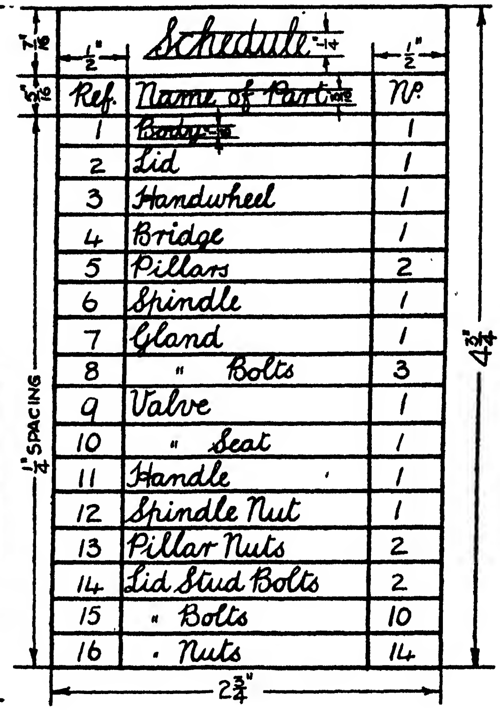


FIG. 12b

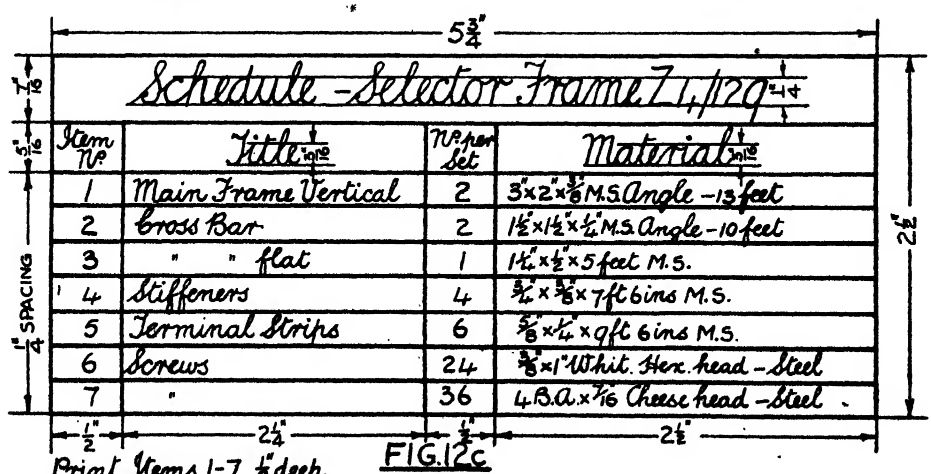


FIG. 12c

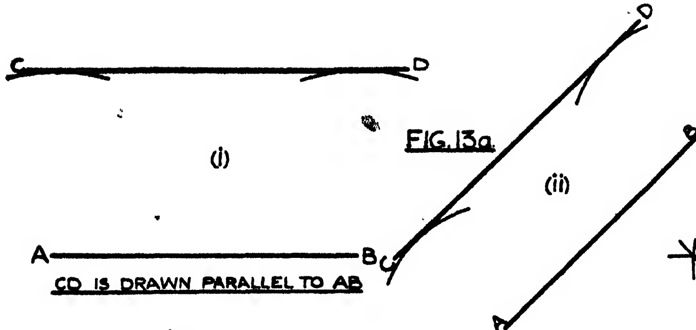


FIG. 13a.

CD IS DRAWN PARALLEL TO AB

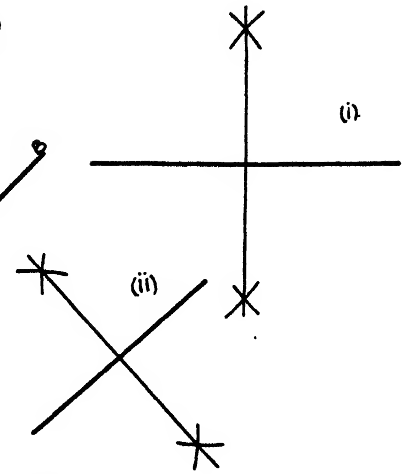


FIG. 13b. PERPENDICULAR BISECTOR

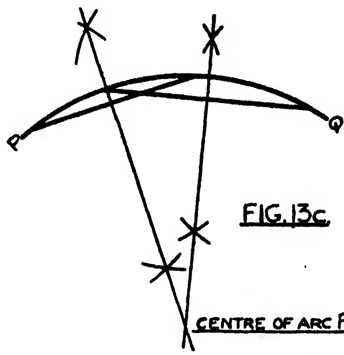


FIG. 13c.

CENTRE OF ARC PQ

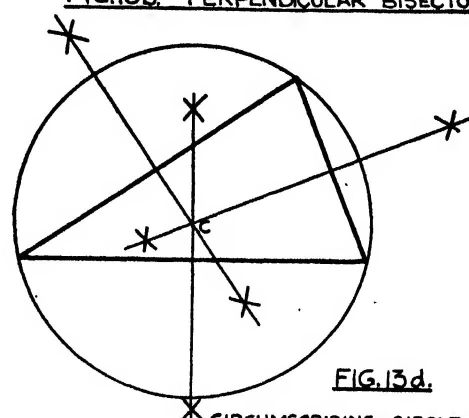


FIG. 13d.

CIRCUMSCRIBING CIRCLE

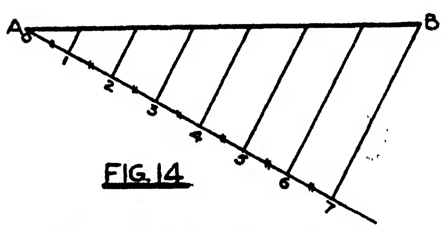


FIG. 14

EQUAL DIVISION OF LINE

1, 2, 3, etc., draw lines parallel to B7, to cut AB. These lines will divide AB into equal parts. This construction can also be applied to divide a line in parts to a given ratio, such as into ratio AC : CB as 3 : 4, or AD : DB as 5 : 2, and it is used in making special scales as described on page 13.

Construction IV

To set off a line inclined to a given line at an angle equal to a given angle. Describe an arc of any convenient radius, to cut both lines of the given angle at A and B, and an arc of equal radius from the end of the given line (fig. 15). Set compasses to the distance from A to B, and with this radius cut off a length along the arc from the given line equal to AB. Join end of the given line to this mark, to form the required angle.

Construction V

To bisect an angle. Any angle, acute, obtuse or reflex, may be divided equally by a straight line through the apex. From the apex of the angle, mark off any equal distance along each line of

the angle. From these marks describe arcs with a suitable radius, to intersect within the angle. The line joining the apex to the intersection of the arcs will bisect the angle. If the converging lines are too far apart or angle is too small, so that they do not intersect on the sheet, lines parallel to and equidistant from the two given lines should be drawn and the angle between them bisected (fig. 16*a*).

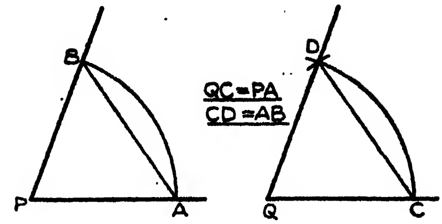


FIG. 15.
CONSTRUCTION OF EQUAL ANGLE

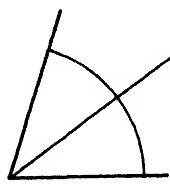
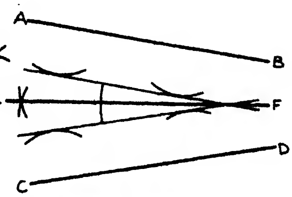


FIG. 16a



EF BISECTS ANGLE BETWEEN AB AND CD.

BISECTION OF ANGLE

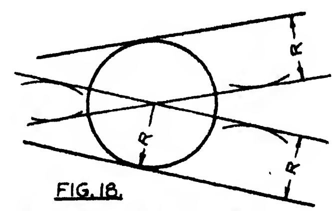


FIG. 18.
ARC TO TOUCH GIVEN LINES

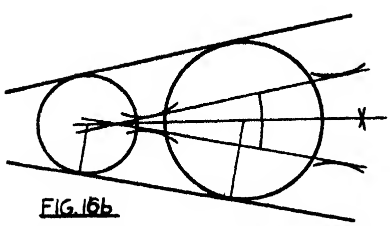


FIG. 16b
CENTRES OF CIRCLES TO TOUCH LINES

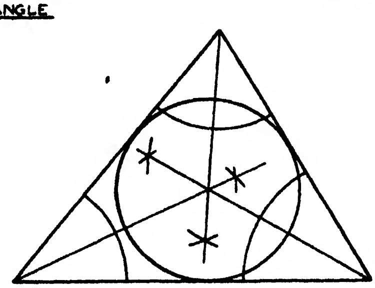


FIG. 16c
INSCRIBED CIRCLE

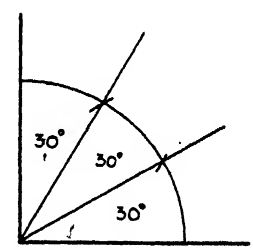


FIG. 17
TRISECTION OF RIGHT ANGLE

Application I. To draw circles to touch or to be at equal distance from two converging lines. The centres of all the circles will be on the line bisecting the angle (fig. 16*b*).

Application II. To draw a circle to touch each side of any triangle. The lines bisecting each angle will all meet at one point, the centre of the inscribed circle (fig. 16*c*).

Construction VI

To trisect a right angle. With any convenient radius, describe an arc to cut both lines of the angle. With the same radius, mark off from the intersection of arc and lines a distance along the arc. Check that middle length of arc is equal to both end lengths (fig. 17).

Construction VII

To describe circle of a given radius to touch two converging lines. By Construction I draw lines parallel to and distant from the given lines by a length equal to the given radius. The intersection of these parallel lines will be the centre of the required circle (fig. 18).

Construction VIII

To describe circles of a given radius to touch two given circles (*a*) externally, (*b*) internally.

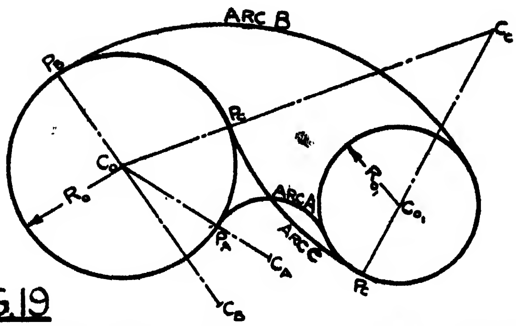


FIG. 19

GIVEN CIRCLES CENTRES C_o AND C_{o_1}, RADII R_o AND R_{o_1}

EXTERNAL CONTACT

ARC A – RADIUS R_A, CENTRE C_A
POINTS OF CONTACT P_A. $C_oC_A = R_o + R_A$, $C_{o_1}C_A = R_{o_1} + R_A$

INTERNAL CONTACT

ARC B – RADIUS R_B, CENTRE C_B
POINTS OF CONTACT P_B. $C_oC_B = R_B - R_o$, $C_{o_1}C_B = R_B - R_{o_1}$

INTERNAL-EXTERNAL CONTACT

ARC C – RADIUS R_C, CENTRE C_C
POINTS OF CONTACT P_C. $C_oC_C = R_o + R_C$, $C_{o_1}C_C = R_C - R_{o_1}$

Lines joining the centre of the required circle to the centre of the given circle will pass through the point of contact of the circles, and will be of length equal to the sum of the radii of the given and required circles for external contact, and to the difference for internal contact. The centre of required circle is found, therefore, by describing intersecting arcs from centres of given circles, of radius $R_O + R_A$ and $R_{O1} + R_A$, or $R_B - R_{O1}$ and $R_C - R_{O1}$ (fig. 19).

By combining Constructions VII and VIII, circles may be drawn to touch a given line and a given circle.

USE AND CONSTRUCTION OF SCALES

It is often inconvenient to draw views of an object to its actual full size; representations which are in proportion, but not of true size, are said to be drawn to scale. Usually

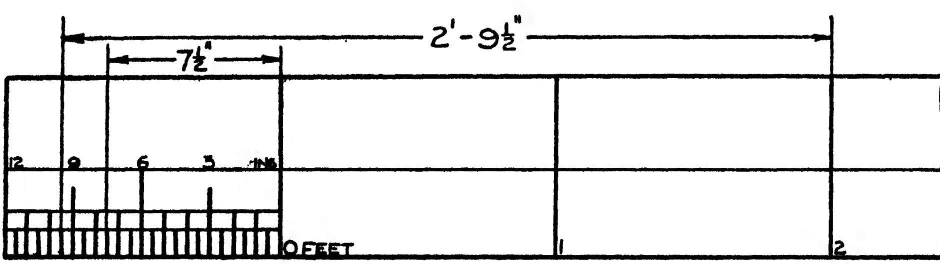


FIG. 20 SCALE FOR MAKING DRAWINGS TO A SCALE OF 1½"–1 FOOT

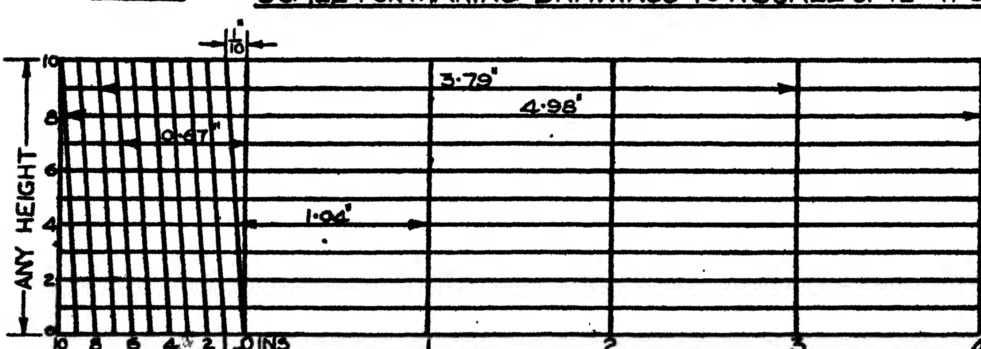


FIG. 21 DIAGONAL SCALE READING TO ·01" (1/100) UP TO 5"

such drawings are smaller than the original, the object being too large to draw on a normal standard size sheet, but sometimes a very small detail is drawn larger than the original to show the small shapes and dimensions more clearly. (See fig. 86, page 69.)

For convenience, when drawing to scale, simple reductions or enlargements are made such as $\frac{1}{2}$, $\frac{1}{4}$ or $\frac{1}{8}$ full size, or twice, four or ten times full size. Awkward sizes such as $\frac{3}{8}$, $\frac{5}{8}$, etc., are inconvenient to use; $\frac{3}{4}$ in. to represent 1 ft. ($\frac{1}{16}$ full size) and similar reductions are often used for large structures.

Fig. 20 shows the construction of a scale which allows easy reading of any dimension within its range. Notice that only one division is fully divided, and numbers read each way from this division; note also the horizontal lines to separate the smaller subdivisions. This type of scale is convenient for scale drawing when a scale rule is not available.

DIAGONAL SCALE

Accurate subdivisions may be obtained by drawing a diagonal scale as shown in fig. 21 which shows a scale to read to hundredths of an inch up to 5 in. The sloping lines subdivide each one-tenth in proportion, giving hundredths of the inch. Similar scales may be constructed to give readings to $\frac{1}{8}$ in. on a reduced scale of 1 in. to represent 1 ft., by making twelve divisions of the inch and diagonal lines across eight equal horizontal spaces ($\frac{1}{8}$ of $\frac{1}{12} = \frac{1}{96}$), *i.e.*, $\frac{1}{8}$ in. to scale $\frac{1}{12}$ full size.

EXERCISE III

Each question will fit into the size shown, a sub-division of a half imperial sheet:

(1) Draw a line about 5 in. long and perpendicularly bisect it. Number the four right angles as shown (fig. 22). Bisect angle 2, trisect angle 3. In angle 1 draw line to form two unequal acute angles, and join the arms of the larger angle by an arc of $\frac{3}{4}$ in. radius. In angle 4 construct acute angles equal to those in angle 3. On figure mark the following angles and check with a protractor: (*a*) 75°, (*b*) 105°, (*c*) 120°, (*d*) 135°. ($7\frac{1}{2} \times 7\frac{1}{2}$)

(2) With a sharp-pointed pencil, draw an arc round the edge of a semicircular protractor. Find the centre and check with a pair of compasses. ($7\frac{1}{2} \times 7\frac{1}{2}$)

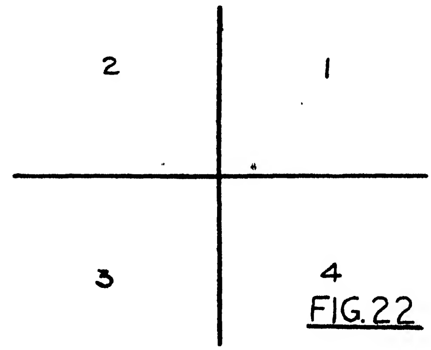


FIG. 22

(3) Draw a triangle ABC, AB 3 in., BC 2 in. and CA $3\frac{1}{4}$ in.

(*a*) Describe a circle to pass through AB and C.

(*b*) Describe a circle to touch each side of triangle.

(*c*) Describe a circle to touch side BC and AB, AC produced. ($7\frac{1}{2} \times 7\frac{1}{2}$)

(4) A and B are two points $3\frac{1}{2}$ in. apart, $1\frac{1}{2}$ in. from a fixed line. On centre A describe a circle 2 in. diameter and on centre B a circle $2\frac{1}{2}$ in. diameter.

(*a*) Draw an arc of $\frac{3}{4}$ in. radius to touch the larger circle and the line.

(*b*) Draw an arc of $1\frac{1}{4}$ in. radius to touch both circles externally.

(*c*) Draw an arc of 4 in. radius to touch both circles externally.

(*d*) Draw an arc of 4 in. radius to touch the smaller circle externally and the larger internally. ($7\frac{1}{2} \times 7\frac{1}{2}$)

(5) Use the constructions to draw the figures shown. (*c*) four times (*h*) twice full size.

(*a*) Star handwheel (fig. 23*a*) ($5\frac{1}{2} \times 7\frac{1}{2}$).

(*b*) Valve handwheel (fig. 23*b*) ($5\frac{1}{2} \times 7\frac{1}{2}$).

(*c*) Contact spring (fig. 23*c*) ($5\frac{1}{2} \times 3\frac{3}{4}$).

(*d*) Key (fig. 23*d*) ($11 \times 3\frac{3}{4}$).

(*e*) Spanner (fig. 23*e*) ($11 \times 3\frac{3}{4}$).

(*f*) Machine handle (fig. 23*f*) ($5\frac{1}{2} \times 7\frac{1}{2}$).

(*g*) Crane hook (fig. 23*g*) ($5\frac{1}{2} \times 7\frac{1}{2}$).

(*h*) Extruded section (fig. 23*h*) ($5\frac{1}{2} \times 3\frac{3}{4}$).

(6) Construct a diagonal scale to read $\frac{1}{100}$ in. up to 5 in. From this mark off line 3·94 in. long, and by construction divide into ten equal parts. Measure each part with a centimetre rule.

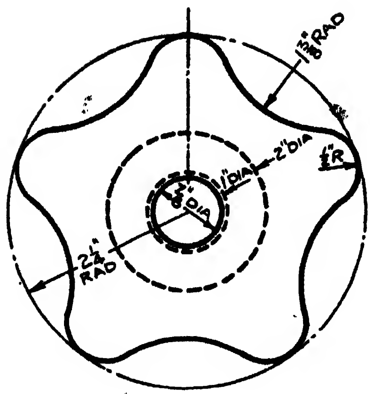


FIG. 23a—STAR HANDWHEEL

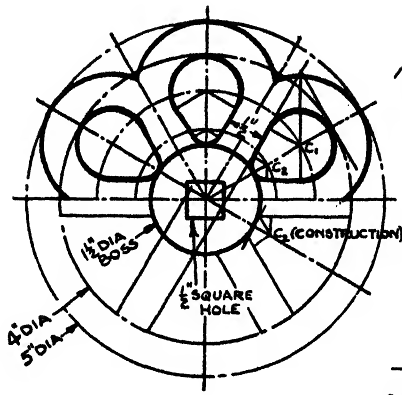


FIG. 23b—VALVE HANDWHEEL
(INCOMPLETE)
60° SET SQUARE EXERCISE

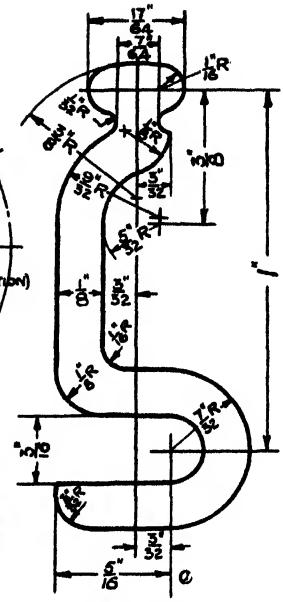


FIG. 23c
CONTACT SPRING

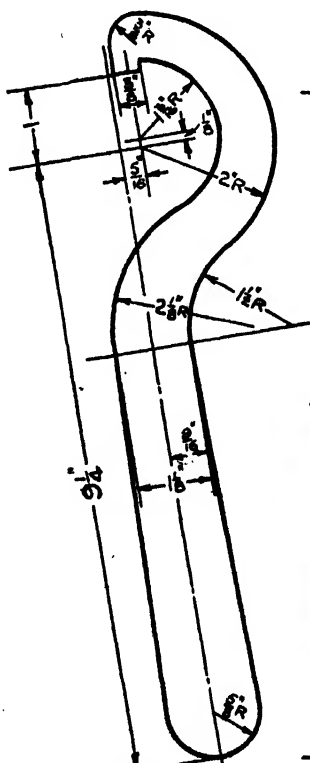


FIG. 23d
KEY

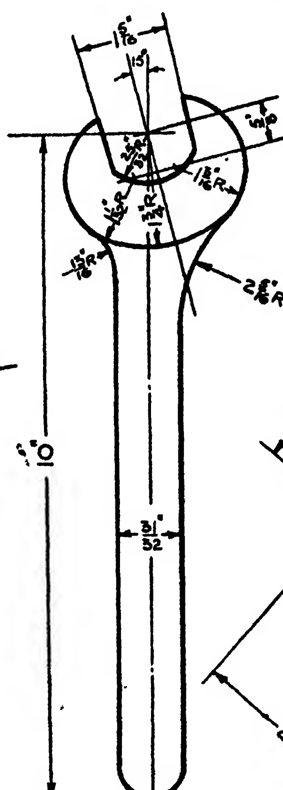


FIG. 23e
SPANNER

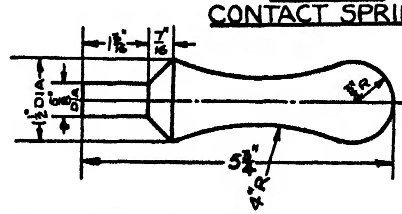


FIG. 23f—MACHINE HANDLE

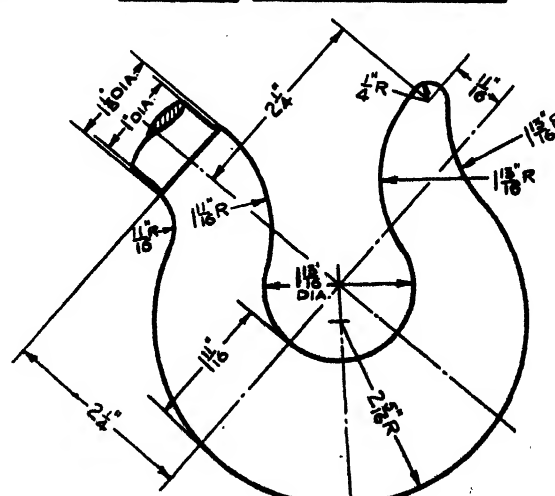


FIG. 23g
CRANE HOOK

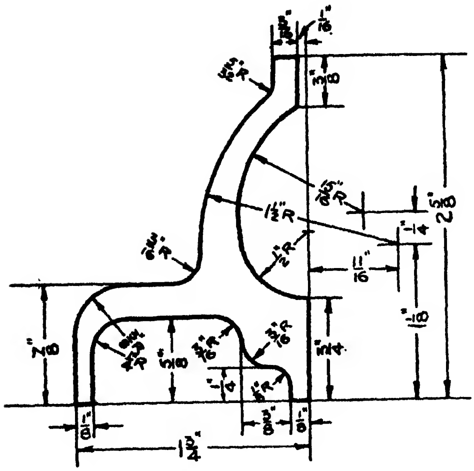


FIG. 23h-EXTRUDED SECTION

THE LOCUS OF A POINT

(Plural LOCI)

Any line may be considered as the successive positions of a moving point; and the path of any point moving according to some prescribed law is called the locus of the point. For example, the locus of a point moving so that it is always at a given distance from a straight line is a parallel straight line, or the locus of a point moving so that it is always at a given distance from a fixed point is a circle. Several important curves are obtained by tracing the locus of a point and some of them are given below. In plotting the locus of any point, it is necessary to construct the figure of which the point is a part moving according to the given law, and from these constructions to determine the position of the point on the figure at successive instants.

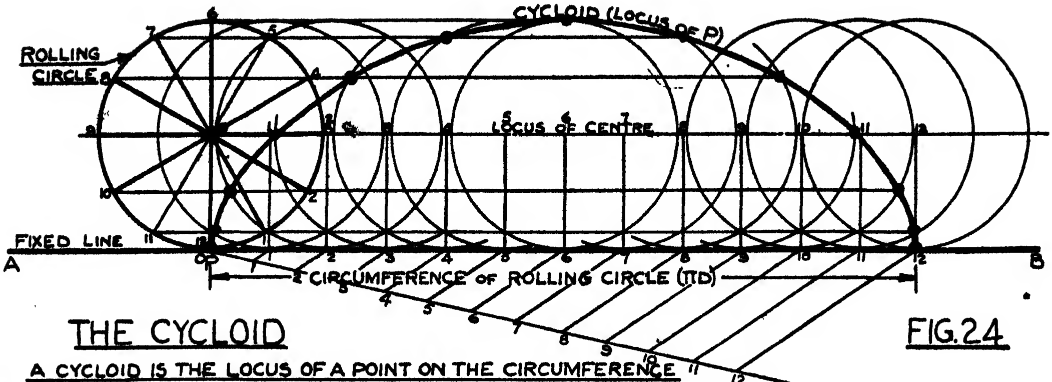
THE CYCLOID

When a circle rolls along a line (*e.g.*, a wheel rolling on a straight road), any point on the circumference traces out a cycloid. Consider a point P on circle, fig. 24, which rolls along line AB. The point will touch the line at successive positions at a distance apart equal to the circumference of the circle, and half way between these positions the point will be at the top of the circle. To plot the locus, mark off along the line a length equal to the circumference of the rolling circle, and divide this equally into a number of parts, say 12. Draw the circle with point P on the first mark O, and divide the circle into the same number of equal sectors as the divisions of the line (in this case 12, each angle $\frac{360^\circ}{12} = 30^\circ$). Through the centre of the circle draw a line parallel to AB, and perpendicular lines through the equal divisions 1–12 to mark successive positions of the centre as the circle rolls along. The arc of each sector is equal to one division of the line; hence in one-twelfth of a revolution point 1 on circle will move down and along to position 1 on AB, while P will move to height at which point 11 was formerly. P, therefore, is at this height on the circle in its second position, as indicated by the projected line. Further positions may be plotted in a similar manner until the circle has made a complete revolution. Note that after position 6, P having reached the top of the circle, the following points will be on the opposite side of the circle to those in earlier positions.

Application. The cycloid is the form of curve used in certain gear teeth. It was formerly used more extensively, but modern production methods tend to limit the application to small gears such as those on instruments. The actual curve used is a double curve each tooth having an epicycloid and a hypocycloid in its contour. The teeth of milling cutters move with reference to the work, in a path of cycloidal form in certain operations.

THE EPICYCLOID AND HYPOCYCLOID

A point on the circumference of a circle rolling on the outside of another



THE CYCLOID

FIG. 24

A CYCLOID IS THE LOCUS OF A POINT ON THE CIRCUMFERENCE OF A CIRCLE WHICH ROLLS, WITHOUT SLIDING, ALONG A FIXED STRAIGHT LINE.

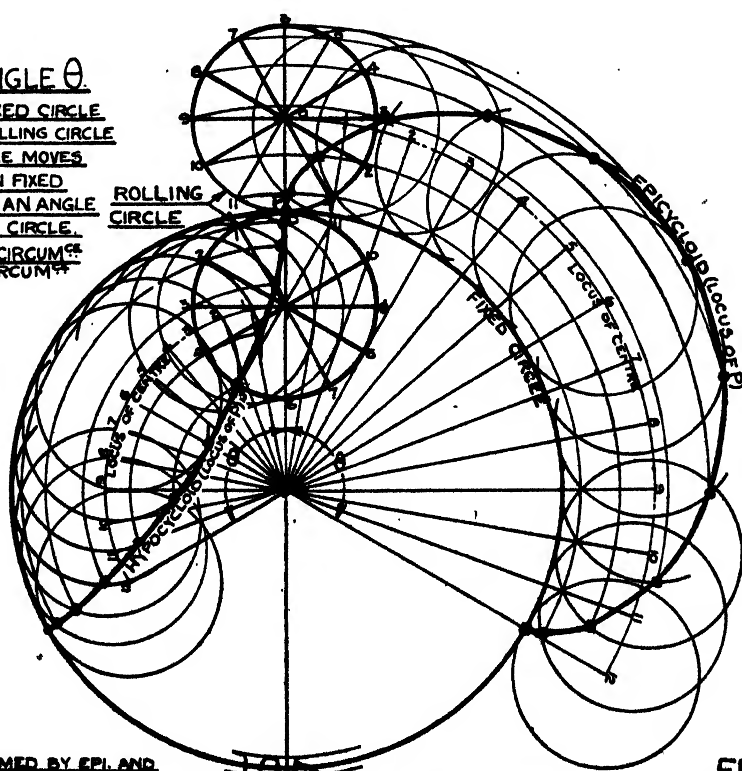
TO FIND ANGLE θ.

IF D = DIA. OF FIXED CIRCLE AND d = DIA. OF ROLLING CIRCLE IN 1 REV. ROLLING CIRCLE MOVES OVER AN ARC = πd ON FIXED CIRCLE SUBTENDING AN ANGLE θ AT CENTRE OF FIXED CIRCLE.

$$\frac{\theta^\circ}{360^\circ} = \frac{\text{ROLLING CIRCLE CIRCUM}^{CE}}{\text{FIXED CIRCLE CIRCUM}^{CE}}$$

$$\frac{\theta^\circ}{360^\circ} = \frac{\pi d}{\pi D}$$

$$\therefore \theta^\circ = \frac{d}{D} \times 360^\circ$$



SHAPES OF TEETH FORMED BY EPI. AND HYPOCYCLOIDS ARE CALLED 'CYCLOIDAL'. (FORMERLY USED ON CAST GEAR WHEELS FOR LOW SPEED MACHINERY.)

FIG. 25

EPICYCLOID—IS THE LOCUS OF A POINT ON THE CIRCUMFERENCE OF A CIRCLE WHICH ROLLS, WITHOUT SLIDING, ON THE OUTSIDE OF A FIXED CIRCLE.

HYPOCYCLOID—IS THE LOCUS OF A POINT ON THE CIRCUMFERENCE OF A CIRCLE WHICH ROLLS, WITHOUT SLIDING, ON THE INSIDE OF A FIXED CIRCLE.

circle traces out an epicycloid, while if the circle rolls on the inside of the other, the point traces out a hypocycloid (fig. 25). The point P, starting from the base circle, will again reach the base circle when the rolling circle has moved round an arc equal in length to the circumference of the rolling circle. Since each circumference is proportional to the respective radius, we can calculate what fraction of the base circle is covered by a complete revolution of the rolling circles. Thus $r : R :: \theta : 360$, where r and R are the respective radii and θ the angle subtended at the centre by an arc equal to the circumference of the rolling circle. To plot the loci, divide the rolling circle and angle θ into the same number of equal parts in order to determine successive positions of the rolling circle. Positions on these circles are found by striking arcs from the centre of base circle, through corresponding points from the initial position.

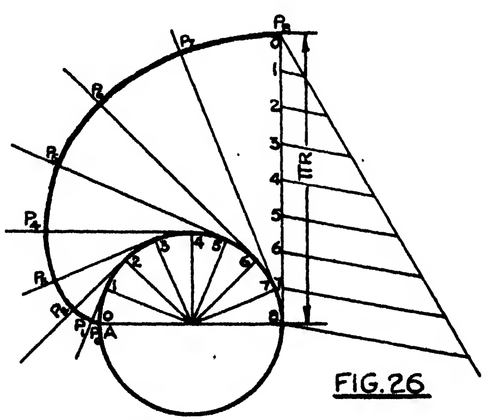


FIG. 26

INVOLUTE OF A CIRCLE
(CURVE USED FOR TOOTH SHAPE OF GEAR WHEELS IN HIGH SPEED MACHINERY.)

THE INVOLUTE

If a circle is fixed and a straight line rolls off the circle, points on the line trace out involutes. For example, the end of a cord, held taut and unwrapped from a reel, makes an involute. As before, calculate the circumference, and divide the circle and the line of length equal to the circumference into the same number of equal parts (fig. 26). Draw tangents to the circle from the end of each radial dividing line. Starting from A, if line unwraps $\frac{1}{16}$ of a revolution, it will be in a position along the tangent from point 1, and $\frac{1}{16}$ of circumference will be unwrapped. From 1 step off $\frac{1}{16}$ of circumference along tangent to find position of P, and so on for each successive unwrapping.

(Note.—Fig. 26 shows involute traced by unrolling half a circle only.)

Application. This is a most important locus, since it gives a curve which has excellent characteristics for gear teeth, and is also comparatively easy to produce accurately.

CONIC SECTIONS

When a cone is cut by a flat surface, one of four different curves is obtained according to the position of the surface,

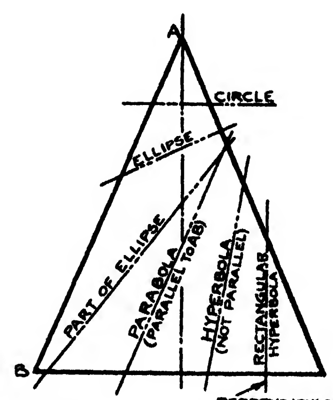


FIG. 27—SECTIONS OF A CONE

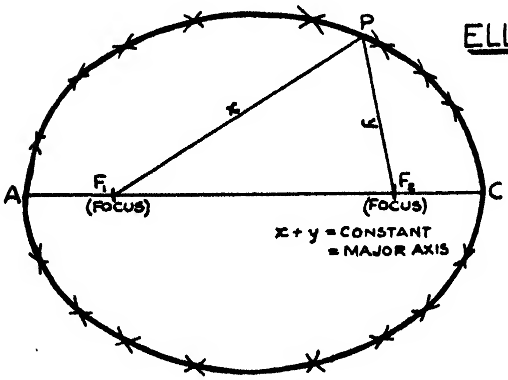
as shown in fig. 27. All these curves can be plotted as loci. The ellipse is the shape seen when looking on a tilted circular surface such as the end of a round bar. It is also the shape required for a reflector designed to focus a spot of light on one point, and is approxi-

mately the path of points on several parts of mechanisms. The parabola occurs very frequently in practice, being the path traced by a projectile, the path of a jet of water, the shape of a reflector for parallel beams, such as in searchlights, and the theoretical shape of teeth for milling cutters, etc.

CONIC SECTIONS AS LOCI

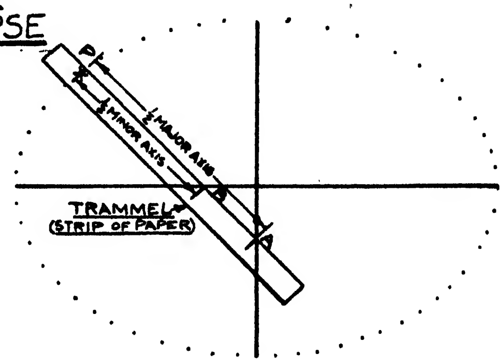
The Ellipse. An ellipse is the locus of a point which moves so that the sum of its distance from two fixed points is a constant. Each fixed point is a focus, and the constant sum is equal to the longest distance across the ellipse, called the major axis.

AN ELLIPSE



GIVEN FOCI F_1 AND F_2, AND MAJOR AXIS AC. $F_1P + PF_2$ ALWAYS EQUALS AC

FIG. 28a



MARK POINT P AT ONE END OF STRIP, AND SET OFF PA AND PB EQUAL TO ½ MAJOR AND ½ MINOR AXES RESPECTIVELY. KEEPING A AND B ALWAYS IN CONTACT WITH AXES, PLOT LOCUS OF P AS A AND B MOVE OVER AXES.

USING A TRAMMEL

FIG. 28c

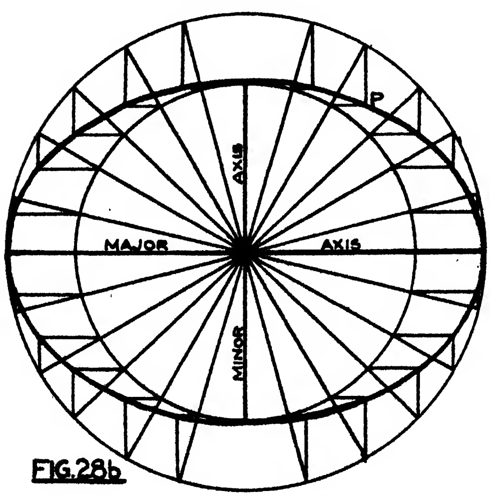
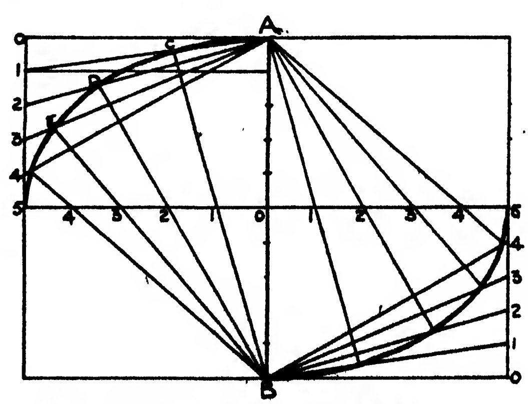


FIG. 28b

USING AUXILIARY CIRCLES



DRAW THE RECTANGLE WITH AXES AS SIDES. DIVIDE SEMI MAJOR AND SEMI MINOR AXES INTO SAME NUMBER OF EQUAL PARTS. DRAW RADIAL LINES FROM A AND B AS SHOWN, TO GIVE POINTS C, D, E, ETC ON CURVE.

USING CIRCUMSCRIBING RECT:

FIG. 28d

METHOD OF PLOTTING

(1) Given Major Axis and Focal Points F_1, F_2 (fig. 28*a*)

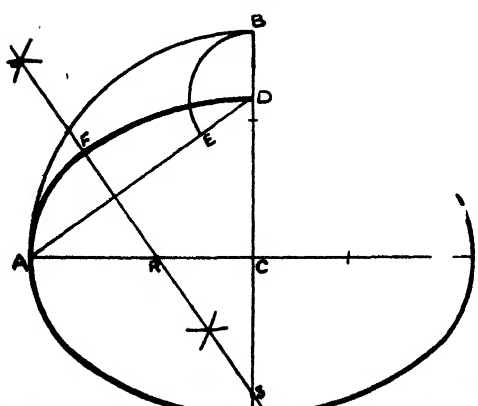
Suppose major axis is 10 in. long, then distance from F_1 to any point P on ellipse + distance from same point P back to F_2 = 10 in. If F_1P = 3 in., then F_2P = 7 in. Hence with radii 3 in. and 7 in. strike intersecting arcs from F_1 and F_2 to give points P on either side of the major axis. Continue for other values of F_1P, PF_2 until sufficient points are obtained to give a fair curve by joining all the intersections.

(2) Given Major and Minor Axes (fig. 28*b*)

Describe circles of radius half major and half minor axis, and from centre draw line to circumference of larger circle. From points where this line touches larger and smaller circle draw lines parallel to the minor and major axes respectively to meet in P. Repeat for various positions of P and join by a fair curve.

Other methods are shown in figs. 28*c* and 28*d*.

(3) To Construct an Approximate Ellipse (fig. 28*e*)

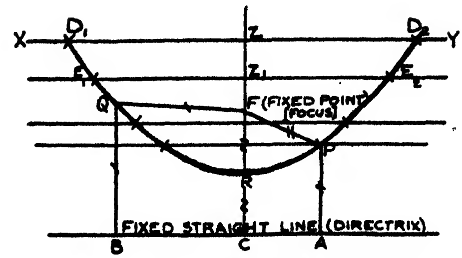


WITH C AS CENTRE AND SEMI MAJOR AXIS AS RADIUS DESCRIBE ARC AB. JOIN AD. WITH D AS CENTRE DRAW ARC BE. BISECT AE AT RIGHT ANGLES TO GIVE CENTRES R AND S. RA AND SD ARE RADII OF CURVE AFD.

FIG. 28e

USING COMPASSES

(APPROXIMATE ELLIPSE)

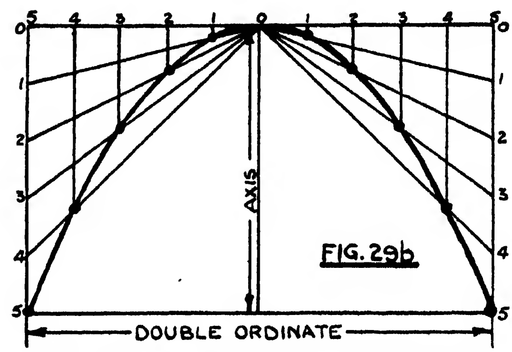


FOR ANY POINT P ON THE CURVE FP = PA.

$\frac{FP}{PA} = \frac{FQ}{QB} = \frac{FR}{RC} = 1$

DRAW LINES PARALLEL TO DIRECTRIX (e.g. XY) AND MARK OFF ITS DISTANCE CZ FROM F AS CENTRE TO OBTAIN POINTS D_1 AND D_2, E_1 E_2 ETC.

PARABOLA FIG. 29a



METHOD OF DRAWING A PARABOLA

(GIVEN AXIS AND DOUBLE ORDINATE)

DIVIDE AXIS AND ORDINATE INTO SAME Nº OF EQUAL PARTS

Since the ellipse occurs so frequently in machine drawing, it is convenient to make a figure which looks like an ellipse but is constructed of circular arcs. There are many constructions, of which the figure shown is one of the simplest. Note that it is only like an ellipse; a true ellipse cannot be drawn with compasses.

THE PARABOLA

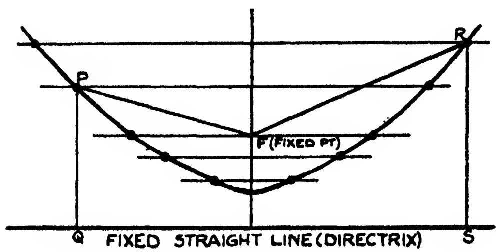
This is the path of a point which is always at a distance from a fixed line equal to its distance from a fixed point. Methods of plotting parabolas are shown in figs. 29*a* and 29*b*.

THE HYPERBOLA

The path of a point which moves so that its distance from a fixed point bears a constant ratio (greater than one) to its distance from a fixed line (see figs. 30*a* and 30*b*).

POINTS ON A MECHANISM

To study the forces which are involved it is often necessary to study the movement of a particular part of a machine. The path through which any point moves during a cycle of operations is called the locus of the point and it is determined by drawing the driving member in several successive positions, and from this obtaining positions of the whole mechanism, and hence of the point concerned. For example, in considering the movement of the connecting rod of an engine while the crank makes one revolution, the end at the crank pin describes a perfect circle relative to the crankshaft, while the further end moves in a straight line along its guides. All other points move in paths between these extremes. Fig. 31 shows the connecting rod in twelve successive positions, and the path of a point, say, ⅓ of the way from the end. The path is almost elliptical; if the connecting rod is infinitely long compared with the crank, the path is truly elliptical. Fig. 32 shows some important mechanical movements, developed for particular purposes, and the loci of points on the mechanisms.



HYPERBOLA

THE LOCUS OF A POINT WHEN

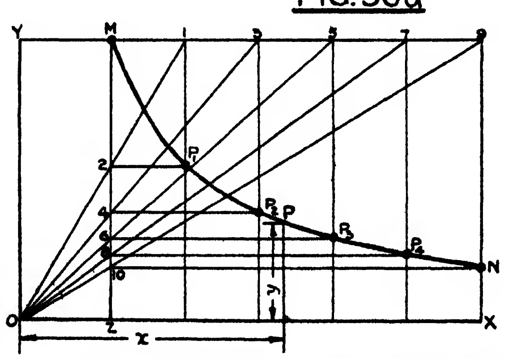
$\frac{FP}{PQ} = \frac{FR}{RS}$ = A CONSTANT (GREATER THAN 1)

WHEN $\frac{FP}{PQ} = 1$ (LOCUS IS A PARABOLA)

WHEN $\frac{FP}{PQ}$ IS LESS THAN 1, LOCUS IS AN ELLIPSE

IN FIG. 30a $\frac{FP}{PQ} = \frac{5}{4}$

FIG. 30a



METHOD OF DRAWING A RECTANGULAR HYPERBOLA (GIVEN THE AXES)

GIVEN AXES AND TWO POINTS M AND N ON CURVE:- COMPLETE RECTANGLE YOX9, JOIN O9.
DRAW MZ PARALLEL TO OY. FROM Z WHERE O1 CUTS MZ DRAW 2P₁ PARALLEL TO OX TO GIVE POINT P₁ ON CURVE.
REPEAT TO OBTAIN THE POINTS P₂, P₃ AND P₄.
FOR ANY POINT P ON CURVE:- x TIMES y = OZ×ZM = OX×XN = A CONSTANT

FIG. 30b

EXERCISE IV

(1) Plot the locus of a point on the circumference of a circle 2½ in. diameter when the circle rolls for one complete revolution along a straight line. (14½ × 3¾)

(2) Describe a circle 4½ in. diameter, and draw a vertical line through the centre to cut the circumference. On this line as centre, draw two circles 1½ in. diameter to touch the large circle at same point A, one inside and one outside. Let each circle roll round the large circle in opposite directions and plot the locus of the point A for each rolling circle. (7½ × 7½)

(3) Plot an ellipse having major axis 5 in. and focal points 3½ in. apart. (7½ × 3¾)

(4) Plot an ellipse having major axis 5½ in. and minor axis 3½ in. by auxiliary circle method. (7½ × 7½)

(5) In the crank mechanism shown (fig. 31) OB is 1½ in. long and AB 3½ in. Plot the locus of point P 1 in. from B when crank makes one complete revolution. (7½ × 3¾)

(6) Construct an approximate ellipse using compasses. Major axis 6 in., minor axis 3¾ in. (7½ × 7½)

THE LOCUS OF A POINT P ON A STRAIGHT LINE AB WHEN A MOVES IN A STRAIGHT LINE WHILE B MOVES IN A CIRCLE. (CRANK AND CONNECTING ROD MECHANISM.)

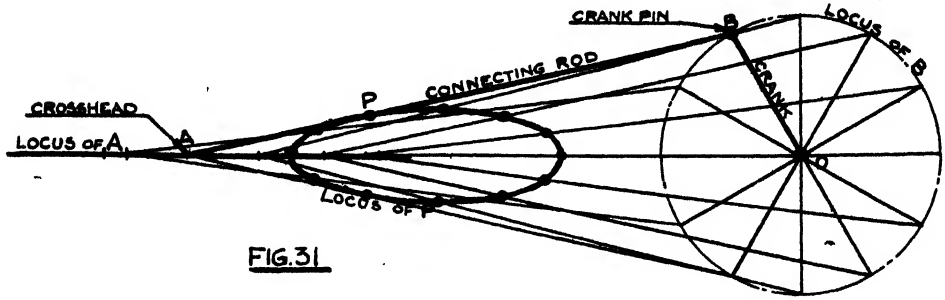


FIG. 31

STRAIGHT LINE MOTIONS

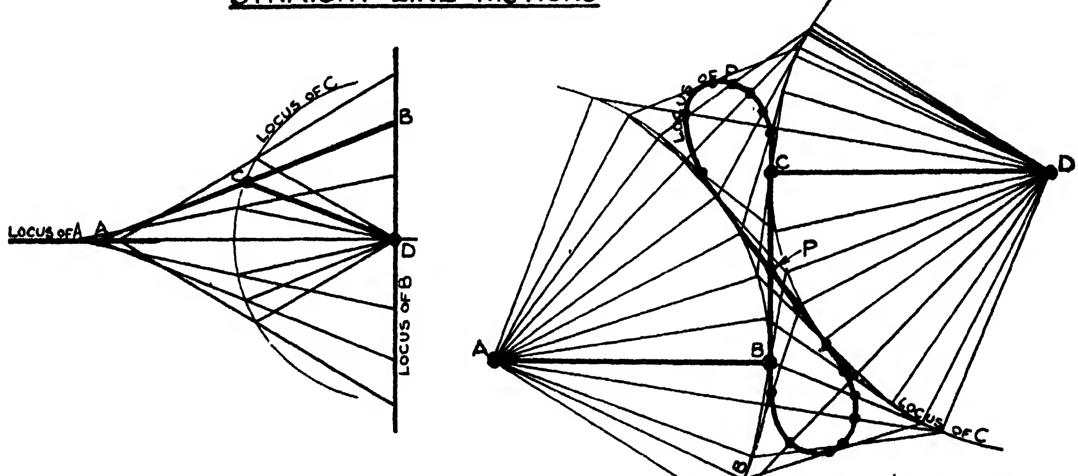


FIG. 32

SCOTT-RUSSELL MOTION

[A MODIFIED FORM IS APPLIED TO INDICATOR FOR FINDING I.H.P. OF AN ENGINE.]

LINK DC TURNS ABOUT FIXED POINT D. C IS THE MID-POINT OF AB AND AC EQUALS CD. WHEN A IS CONSTRAINED TO MOVE IN A STRAIGHT LINE, PART OF THE LOCUS OF B IS ALSO A STRAIGHT LINE.

WATT'S MOTION

(SIMPLE FORM)

[A MODIFIED FORM IS APPLIED TO A BEAM ENGINE.

A AND D ARE FIXED PIVOTS, AND AB = CD. WHEN AB AND DC TURN ON CENTRES A AND D, P THE MID-POINT OF BC TRACES OUT, OVER PART OF ITS LOCUS, A STRAIGHT LINE.

IF AB IS NOT EQUAL TO CD, $\frac{CP}{BP}$ MUST EQUAL $\frac{CD}{AB}$ FOR P TO MOVE IN A ST. LINE.

(7) AB is fixed line and O is fixed point 1½ in. from it. Trace the path of a point P which moves :

- (*a*) so that it is always equidistant from line AB and from O ;
- (*b*) so that it is twice as far from the line as from the fixed point ;
- (*c*) so that it is twice as far from the point as from the line. (7½ × 7½)

(8) Plot the locus of the point P on the valve gearing for a locomotive shown in fig. 33, while link OR makes one complete revolution. (7½ × 7½)

(9) Fig. 34 shows a pantagraph mechanism such as is used on engraving machines, profile cutting machines, etc. A is a fixed pivot, and links BC, CD, DE, EB form a parallelogram. AC and AH are straight lines. Draw an irregular outline and let P be the point

on EB where it crosses the outline in the position shown. With A fixed, plot the locus of D when P moves over the given outline. (Hint.—Strike arcs with AB, PB as radius and hence find new positions of link ABC, BE, and CD as P moves.) ($7\frac{1}{2} \times 7\frac{1}{2}$)

(10) A crank OA is 1 ft. 3 in. long and is connected to a rod AB 6 ft. long, which is constrained to pass through a fixed guide D 4 ft. from O. Plot the locus of the end B and of a point C on AB 2 ft. 6 in. from A.

See additional exercises on page 159.

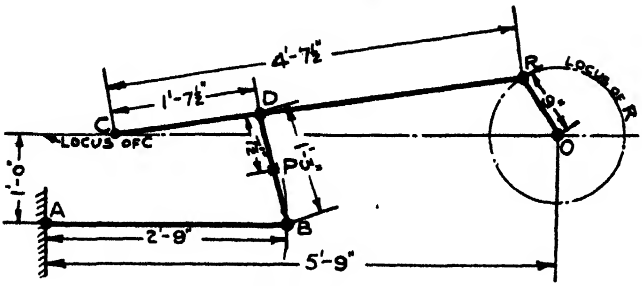


FIG. 33

PLOT LOCUS OF P.

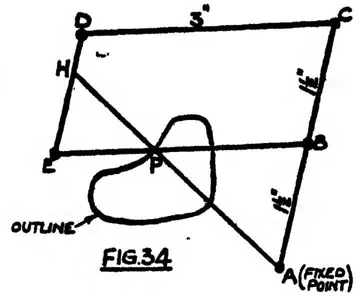


FIG. 34

PICTORIAL REPRESENTATION

It is often necessary to give a descriptive picture of an object, but a clear representation requires considerable skill and artistic ability. There are, however, methods by which, using a set square and tee square, a good pictorial representation is produced quite simply. By studying the examples, it will be seen that details shown by these methods edges of the cube will be equally inclined and will appear of equal length. This illustrates the isometric (iso = equal), or equal measure system; the three observed planes, or surfaces, are in isometric planes. The nearer edges may be represented by lines with equi-angular spaces, so that it is a simple matter to draw a cube by this method, as follows.

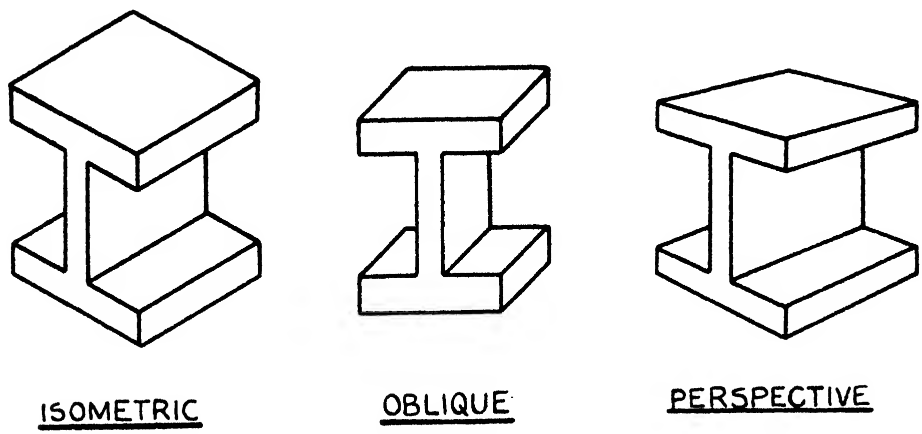


FIG. 35

can be readily visualised, but there is a somewhat top-heavy appearance, due to the fact that the sloping lines are parallel, whereas on a perspective view or on a natural object, the lines would appear to converge. Fig. 35 shows an I-shaped block drawn in accordance with two methods used very frequently, and as a comparison, in perspective.

ISOMETRIC PROJECTION

Let a cube stand on one square face so that one diagonal of the top square is parallel with the observer's eyes. Now let this diagonal remain parallel whilst the cube is tilted forward, so that its upper corner is vertically above the lower corner. In this position all the

TO DRAW AN ISOMETRIC CUBE

Draw three lines spaced at 120° to each other, one being vertical. With the point of intersection as centre, describe a circle to cut off each line, and from the ends draw lines parallel to the first three lines (fig. 36). It will be observed that all these lines can be drawn with a tee square and 60° set square, and are all of equal length, and, further, that the diagonal AB is still seen in its true length, whilst all the edges are shortened.

Suppose the triangle ABC is hinged at AB. Let it turn on the hinges until it stands vertically, and then the sides AC, BC will be seen in their true length. We can in this way compare the true

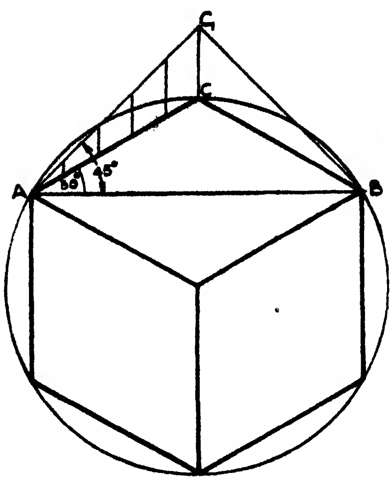


FIG. 36

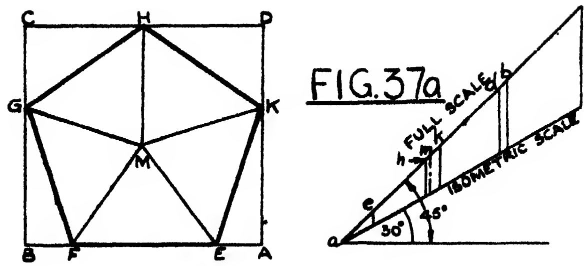


FIG. 37a

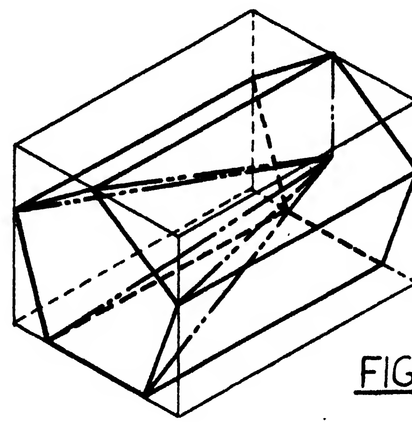


FIG. 37b

and apparent length of lines on the isometric planes, since AC′, BC′ and AC and BC are the true and apparent lengths respectively. If two lines are drawn at angles of 30° and 45° to a third line, true lengths measured along the outer 45° line projected at right angles to the third line will cut the 30° line in proportional, shorter lengths. This is known as an isometric scale, from which true and isometric lengths may be measured. (See fig. 37*a*).

It will be clear that the cube could be extended to represent a rectangular prism which also has all its faces in the isometric planes, and this is a convenient conception, since any object can be "boxed" into such a shape, and the position of points on the object determined on the "box."

For example, to make an isometric drawing of a pentagonal prism or pyramid, say $1\frac{3}{4}$ in. long, it is necessary first to enclose the figure in a box (fig. 37*a*) of the required length, and make an isometric drawing of the box, *i.e.*, a rectangular prism. From the corners of the rectangular face measure off the distance to the points of the pentagon and transfer these points to the corresponding sides on the isometric view, using the isometric scale. The longer edges of the prism are all parallel, and all are therefore drawn sloping at 30° (fig. 37*b*). To draw the pyramid, the pentagonal face would be formed in the same way and the position of the apex determined on the further rectangular face. Then all five corners would be joined to the apex. In a similar manner, any figure which can be put into a rectangular "box" can be drawn in isometric projection.

To represent an object by isometric projection, measurements on all the planes should be taken from an isometric scale, but for convenience the true scale is often used on the isometric axes.

ISOMETRIC CIRCLES

Circles drawn on the face of the cube would all appear as ellipses, and may be drawn by finding the position of several points on the ellipse. Fig. 38 illustrates methods by which this may be done.

In fig. 38*a* the circle is enclosed by a square, and in addition to the four mid-points at which the circle touches the square, four others are fixed by drawing a small square in each corner. By drawing an isometric view of the large and smaller squares, eight points

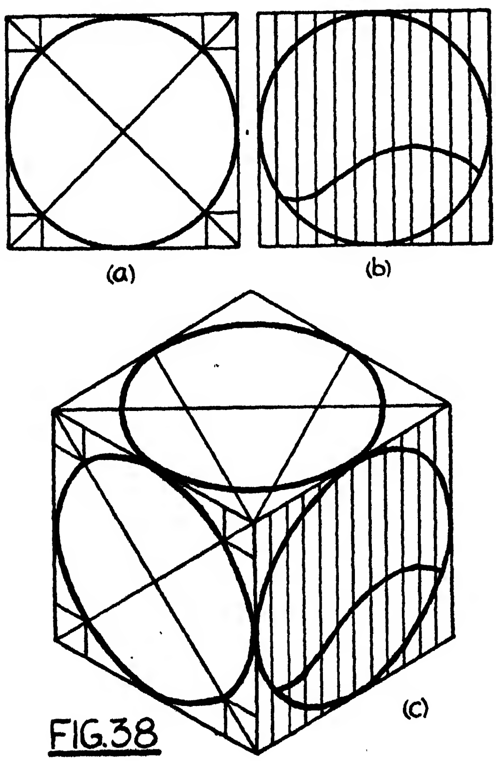


FIG.38

on the ellipse are determined (fig. 38*c*). A more general method is shown in fig. 38*b*, in which the square is divided into strips by either horizontal or vertical lines which cut the circle at two points, and since the lines may be transferred to the isometric view, it is clear that the position of the points on the lines may be found also (fig. 38*c*). This

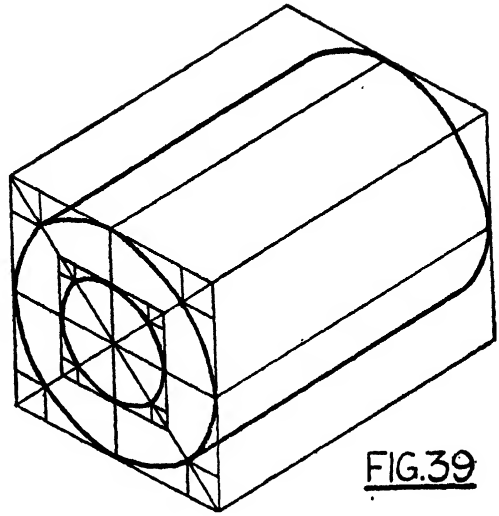


FIG.39

method may be applied to any irregular figures or lines; for example, the line running across the circle of fig. 38*b*.

A convenient approximate method of drawing an isometric circle is shown on the third face of fig. 38*c* where circular arcs are used. Let lines drawn from one corner to the mid-point of the opposite side cut the longer diagonal in two places to mark the centre of circular arcs drawn to touch the sides of the square. The figure is completed by arcs drawn with the ends of the shorter diagonal as centre. Fig. 39 shows how a cylindrical object is represented.

The internal structure of mechanical details can be shown very conveniently in a pictorial view by imagining that a portion of the object is removed exposing the interior. This practice is illustrated by the examples shown in figs. 124*c*, 191*b* and 195.

OBLIQUE PROJECTION

Owing to the inclination of all faces in isometric projection, all circles become elliptical and more awkward to reproduce. If some of the faces are viewed directly from the front this difficulty is avoided. In oblique projection the front face is viewed normally, and therefore the dimen-

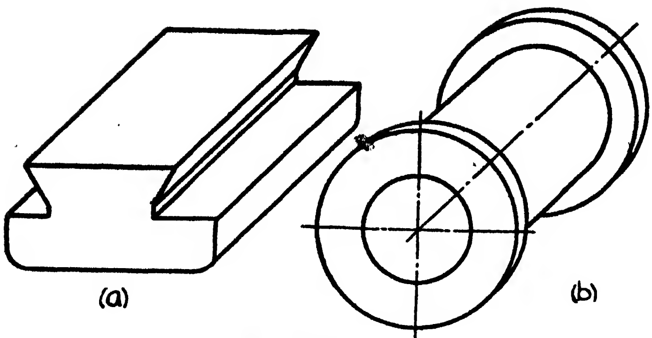


FIG. 40

making of freehand drawings. The principles of isometric and oblique projection are useful in guiding the layout of such work.

sions are true scale and circles appear as circles. The receding edges are shown sloping back at 45° to the right and are shortened to half their true length. Fig. 40 shows two simple objects in oblique projection.

APPLICATION OF PICTORIAL PROJECTION

The foregoing methods of representations of a detail are important not only as a convenient way of making a readily visualised representation, but to assist the student in a very important duty—

EXERCISE V

(1) Make an isometric drawing of a hexagonal prism $1\frac{1}{2}$ in. across flats and $2\frac{1}{2}$ in. long.

(2) Make an isometric drawing of a pyramid $1\frac{1}{2}$ in. $\times$ 1 in. base, $2\frac{1}{4}$ in. high, standing on the rectangular base.

(3) Make an isometric drawing of a cylinder $1\frac{1}{2}$ in. diameter, $2\frac{1}{4}$ in. long, having a $\frac{3}{4}$ in. square hole along its axis.

(4) Make an isometric drawing of the pentagonal block shown in fig. 41*a* lying on a pentagonal face. The block is $\frac{1}{2}$ in. thick and is pierced by a $\frac{3}{4}$ in. square hole.

(5) A bar is machined to the section shown in fig. 41*b*. Make an isometric drawing of a $2\frac{1}{2}$ in. length of the section.

(6) Make an isometric drawing of a curved lever $\frac{3}{4}$ in. thick as shown in fig. 41*c* with boss $1\frac{1}{4}$ in. deep.

(7) Make an oblique projection of the $\frac{3}{4}$ in. plate shown in fig. 41*d*, standing on the $4\frac{11}{16}$ in. edge.

More difficult examples are shown on page 160, and may be attempted after a study of Chapter IV.

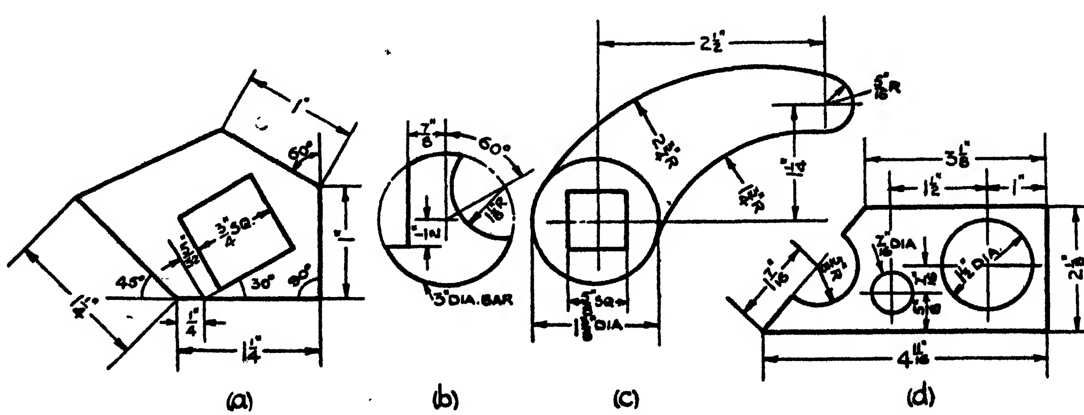


FIG. 41

ORTHOGRAPHIC PROJECTION

WHILST pictorial representations can give a good impression of any object, they are not at all suitable for reproduction for the purpose of manufacturing the object. Even on the representation of a simple object shown pictorially, dimensions and instructional notes are difficult to place and are easily confused. This is because it is impossible to see several faces of any one object from one viewpoint, but by looking from several viewpoints, even the most complicated machine part can be clearly portrayed and all the necessary particulars given for manufacture. Such a collection of views can be shown by an orthogonal or orthographic projection of the object.

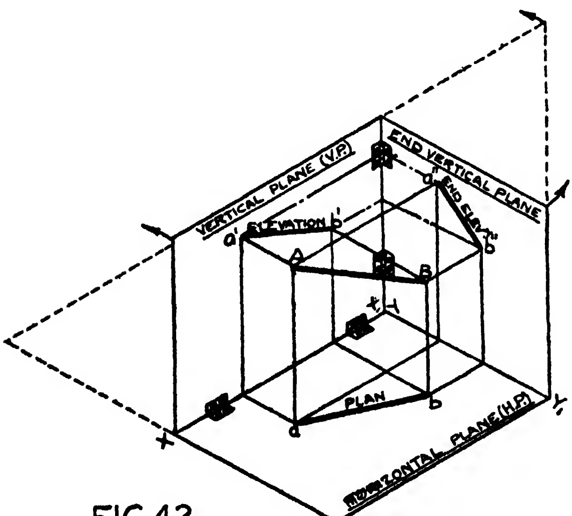
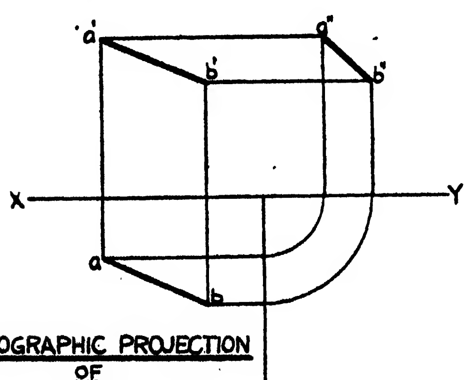


FIG. 42



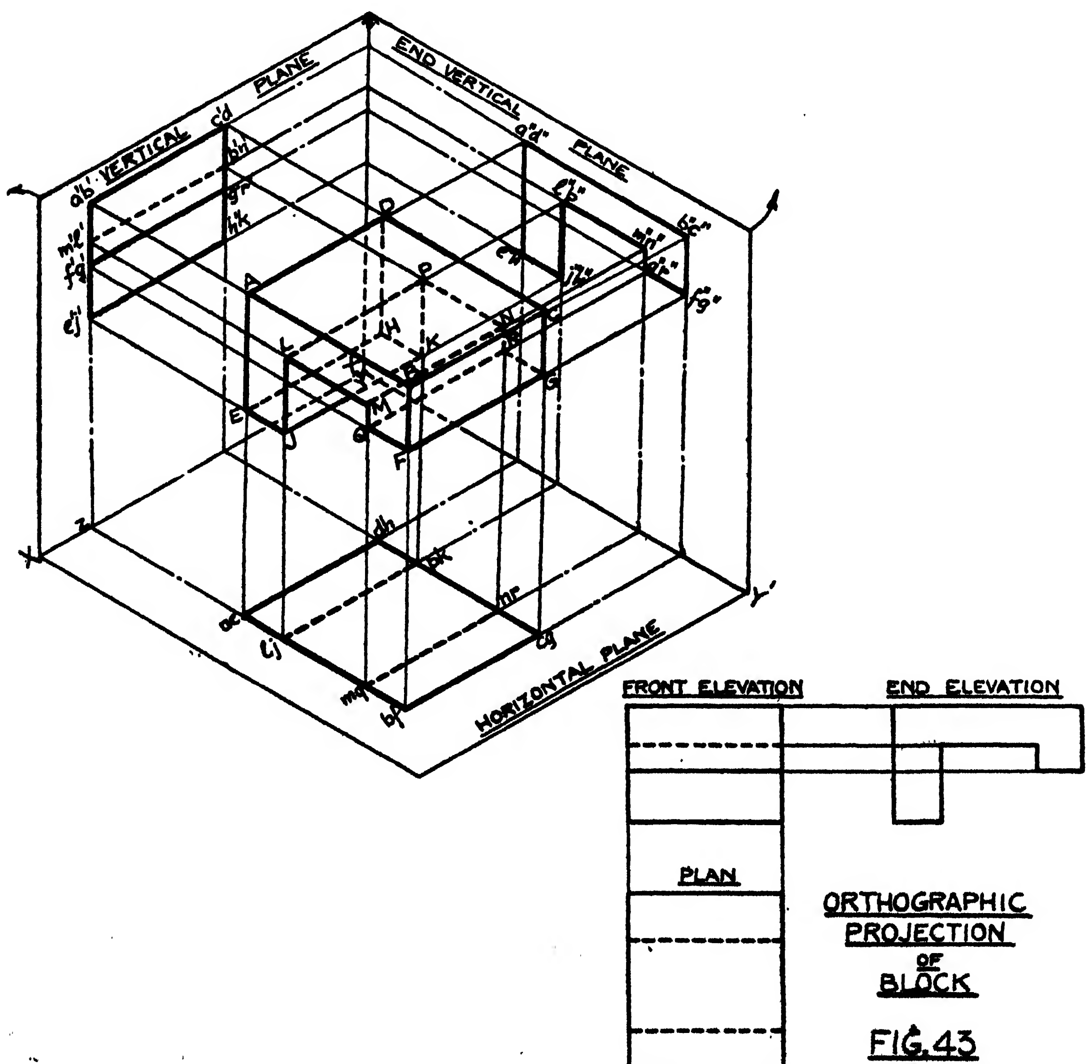
ORTHOGRAPHIC PROJECTION OF LINE

Imagine an open rectangular box standing on its base, and then having the front upright side and the left-hand upright side removed, leaving only two upright sides and the horizontal base. If a tiny ball as small as a pin-head is suspended inside this remaining space, it can be viewed in three ways: (1) by looking down from a position vertically above it; (2) by looking from a position at the same horizontal level immediately in front of it; (3) by looking from another point beside it at the same horizontal level. This gives three pictures of the one point A, one on each of the sides of the box as shown in fig. 42 and the views are orthographic projections of the point A. The flat surfaces of the box are the planes of projection, a plane being merely a flat surface. The bottom of the box is the horizontal plane (H.P.) on which the Plan is seen, the back is the vertical plane (V.P.) on which the Elevation is seen, and the end is the End Vertical plane on which the End elevation is seen. Thus *a* is the plan, *a'* the elevation and *a''* the end elevation of the point A. It must be remembered that the sight lines (or projection lines) are in each case at right angles, or normal, to the plane to which they are directed. Now, if a similar ball is suspended elsewhere in the box, three views of this also can be seen, and by joining the two points a line is formed. Three views of this line are shown by joining the view of each end of the line on all three sides of the box or planes.

If a further point C were introduced,

BC and CA would be two lines which, with AB, form the edges of a flat triangle. The projections of the lines AB, BC, CA would therefore show the orthographic views of a plane triangular surface. Every geometric shape, cube, prism, cylinder, etc., is bounded by faces, each of which is bounded by lines which may be considered as a series of points. By projecting the various points orthogonally we can hence determine the projection of any such figure. It is very important that the student should be able to trace corresponding points, lines and faces from one view to another, and recognise that every point has its position in each view of the object. The same principles apply to machine details which are of course composite geometric shapes.

Fig. 43 shows a block with projection lines marking the view on each of the planes. Let the end plane be hinged and swung round till it is in line with the vertical plane, and then both planes hinged back until all three planes lie horizontal. The three views



ORTHOGRAPHIC PROJECTION OF BLOCK

FIG. 43

are now as they would be shown on a flat sheet of paper. Note that on looking down from above on to the block, point E is directly under A; therefore, the plan of line AE is the point *ae* at the end of projection line on to the horizontal plane. Similarly, looking horizontally across the top surface ABCD, only a straight line is seen, the line *a'b'*, *c'd'* joining the ends of the projection lines from the edges BA, CD to the vertical plane. The surface MLPN is hidden behind the front surface BCGF and therefore it is shown by the dotted line *m'l'*, *p'n'* marked by the projection lines from the edges ML, NP to the vertical plane.

The relationship between views in the three planes is a very obvious point often ignored by students. Each face of the solid is part of a plane surface (B, *a'b'*, Z, *bf*) extending to two of the planes of projection, and for faces such as ABFE which are perpendicular to both the HP and the VP, such a plane is also, of course, perpendicular. The projected views of such faces must therefore be in alignment since Z*bf* is in line with Z*a'b'*. Similarly, the elevation and end elevation of a horizontal surface, such as ABCD, must be at the same height above the HP in both views, and therefore must also be in alignment.

The junction of the HP and VP is usually called the XY line, and this line is both the elevation of the HP and the plan of the VP. In preliminary exercises it is permissible to show the XY line and also faint projection lines, but in later machine drawing neither must be seen. Since the XY line is the plan of the VP, a point which is, say, 2 in. in front of the VP will be 2 in. from the XY line.

The student will have noticed that many machine drawings consist of two views only; it will be very clear, however, that two views are not always sufficient, even for a very simple object; notice for example the similarity of the views of the various objects shown in fig. 44. In some cases more than three views are necessary in order to remove the possibility of a wrong interpretation.

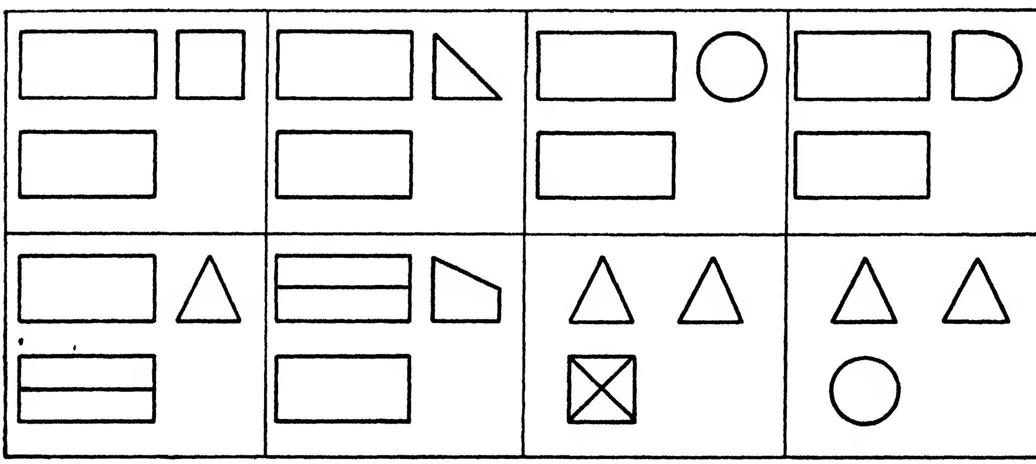


FIG. 44

WORKED EXAMPLES

In the following worked examples the student should check the projection of all the points, lines and surfaces in each view, the position of the solid, and the

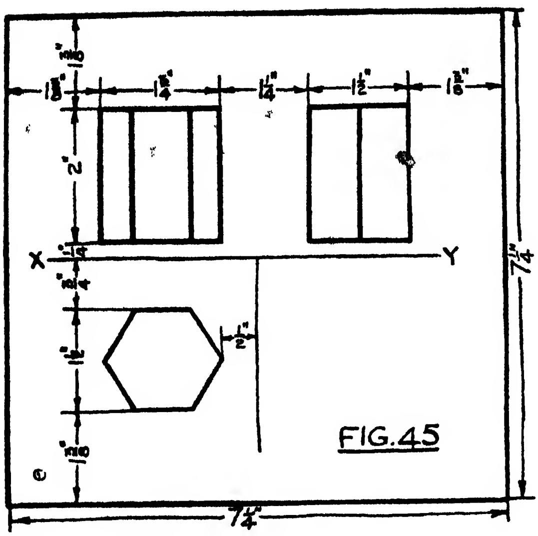


FIG. 45

layout of the three views in the allotted space.

EXAMPLE I

Draw three views of a hexagonal prism having two of its rectangular faces parallel to the VP and hexagonal faces parallel to the HP, height of prism 2 in., distance between rectangular faces 1½ in., nearest rectangular face ¾ in. from the VP, nearest edge ½ in. from end VP, lower hexagonal face ¼ in. from HP. Exercise to be drawn in space 7¼ in. × 7¼ in.

To make a neat drawing, the spacing of the views on paper should be considered. The total width across the corners will be about 1¾ in. (This can be found by drawing a hexagon as shown in Exercise I, No. 1, page 5.) Therefore, the two elevations will occupy a width of 1¾ in. + ½ in. to the end VP + ¾ in. to the end elevation + 1½ in., that is 4½ in. The elevation and plan will occupy height of 2 in. + ¼ in. to HP + ¾ in., to plan + 1½ in., that is 4½ in. (See the rough sketch, fig. 45.) This leaves 7¼ in. − 4½ in. or 2¾ in. in the width, *i.e.*, 1⅜ in. each side, and 7¼ in. − 4½ in. or 2¾ in. spare in the height.

The plan should be drawn first in this case and the other views projected from it; projection lines and construction lines are drawn faintly and the finished drawing then lined in boldly and clearly (fig. 46*a*).

EXAMPLE II

Draw three views of the prism of Example I lying with a rectangular face on the HP, and hexagonal faces inclined at 60° to the VP. The nearest corner is ⅜ in. from VP and ¼ in. from end VP.

(Note.—The elevation of Example I gives shape of the plan in this exercise. Draw this plan in the correct position, and from it project the elevations.) (Fig. 46*b*.)

EXAMPLE III

Draw three views of a pyramid having pentagonal base with 1¼ in. side, nearest edge of base parallel to and ½ in. from VP, nearest corner of base ¼ in. from end VP, base ⅜ in. above HP height of pyramid 2½ in. (For method of drawing pentagon see Exercise I, Nos. 4–5, page 5.) (Fig. 46*c*.)

EXAMPLE IV

Draw three views of the pyramid of Example III tilted about the corner nearest to the end VP till the base is inclined at 30° to HP. (Note.—The elevation of Example III gives shape of elevation in this exercise, and it is drawn in its inclined position. Each point of the base, and the apex, remain at the same distance from the VP, though they have moved toward the end VP. Distances from the VP can therefore be taken from the plan in Example III and the position of the corners and apex projected down from the new elevation to give the plan in Example IV.) (Fig. 46*d*.)

EXAMPLE V

Draw three views of a cylinder 1½ in. diameter, 2¼ in. high, touching HP with axis inclined at 60° to HP, and parallel

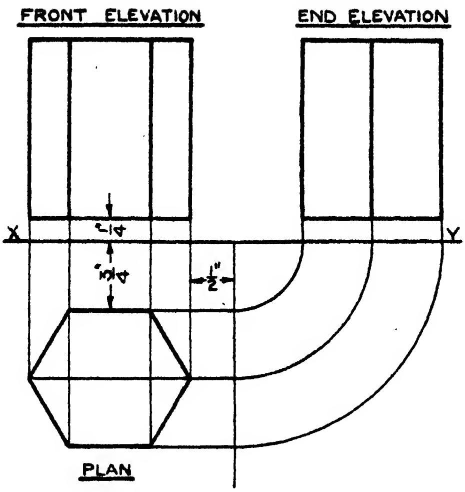


FIG. 46a

PROJECTIONS OF A HEXAGONAL PRISM
2" HIGH, 1½" BETWEEN RECTANGULAR FACES.
2 RECTANGULAR FACES PARALLEL TO THE V.P.
2 HEXAGONAL FACES PARALLEL TO THE H.P.

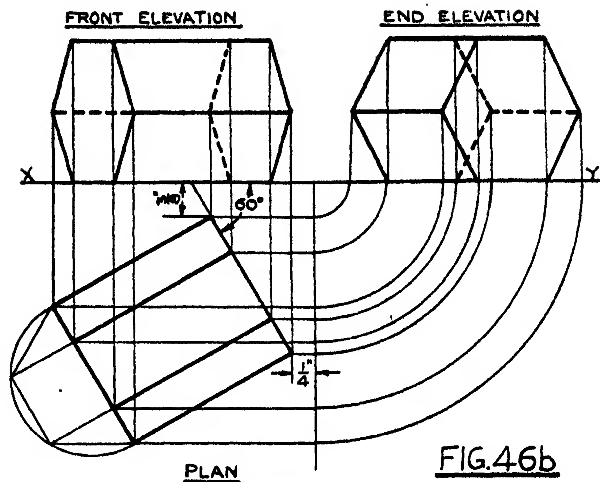


FIG. 46b

PROJECTIONS OF PRISM OF FIG. 46a WHEN
1 RECTANGULAR FACE IS IN THE H.P.
2 HEXAGONAL FACES ARE INCLINED AT 60° TO THE V.P.

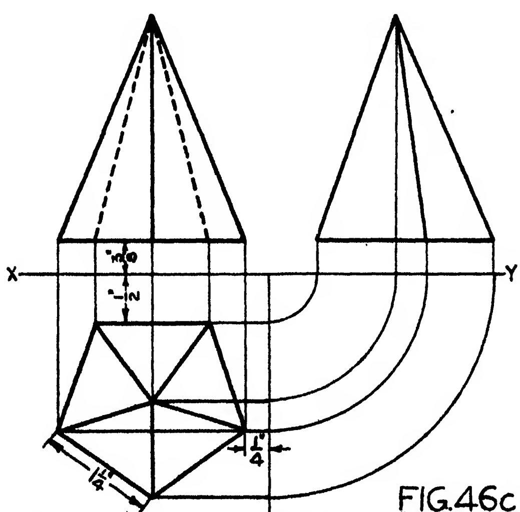


FIG. 46c

PROJECTIONS OF A PENTAGONAL PYRAMID
BASE 1½" SIDE, 2½" ALTITUDE,
WITH BASE PARALLEL TO THE H.P. AND
ONE SIDE OF BASE PARALLEL TO V.P.

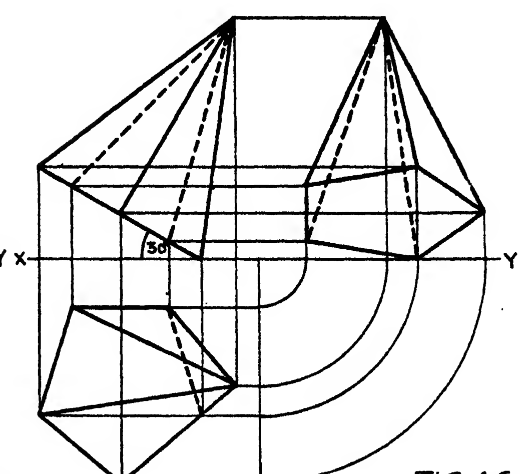


FIG. 46d

PROJECTIONS OF PYRAMID OF FIG. 46c WHEN
ONE CORNER IS IN THE H.P., AND THE
BASE AT 30° TO H.P.
ONE SIDE OF BASE PARALLEL TO V.P.

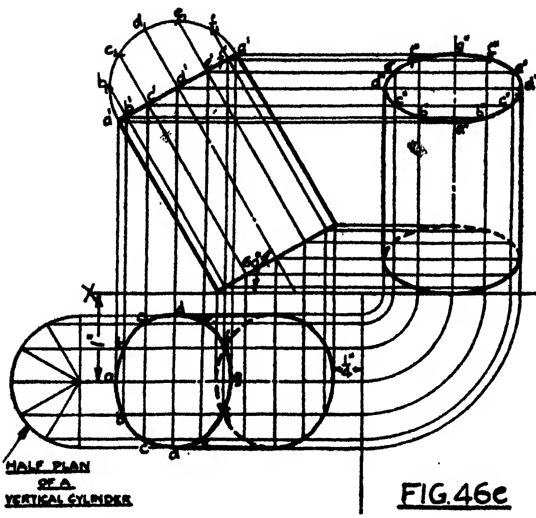


FIG. 46e

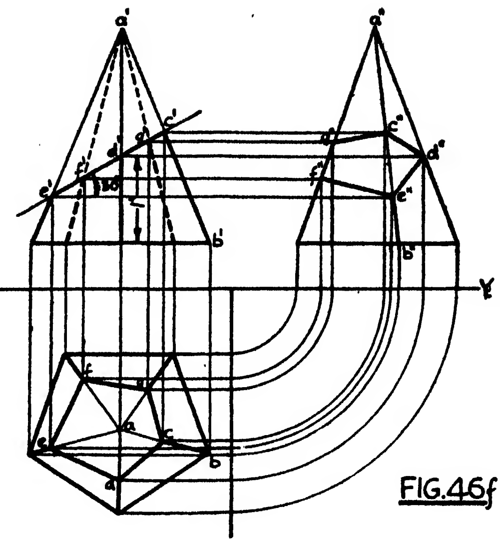


FIG. 46f

PROJECTIONS OF A CYLINDER
1½" DIA. BASE, 2¼" HIGH
WHEN TOUCHING THE H.P.
AXIS PARALLEL TO V.P. INCLINED
AT 60° TO THE H.P.

to and 1 in. from VP, nearest part of cylinder ½ in. from end VP. (Note.—The elevation is a rectangle 1½ in. × 2¼ in. inclined at an angle of 60° to XY line. There are no points or edges on a cylinder, but the circles at the top and bottom can be divided into equal parts and these points projected. If half the upper circle is swung up about the diameter *a'g'* it may be divided equally, and on resuming its position the divisions will be at *b'c'd'*, etc. The half plan of a vertical cylinder with axis at 1 in. from the VP would be as shown. On tilting the cylinder, with the axis remaining parallel to the VP, the points remain at the same distance from the VP and, therefore, may be projected across to meet projection lines from the elevation.) (Fig. 46*e*.)

EXAMPLE VI

The pyramid of Example III is cut off by a plane inclined at 30° to the HP cutting the axis of pyramid 1 in. above its base. Draw the plan and end elevation of the pyramid with the upper part cut off by the plane. (The plane cuts the five sloping edges at five points which may be projected to the plan and end elevations. For example, the edge *a'b'* in the elevation is shown in plan by line *ab*. The point *c'* on this line, therefore, can be projected down to *c* in the plan.) (Fig. 46*f*.)

EXERCISE VI

(1) The lines *ab, bc* (fig. 47*a*) represent the plan of two vertical equilateral triangular plates. Draw their front and end elevations. (5½ × 7½)

(2) The lines *ab, bc* (fig. 47*b*) represent the elevation of two circular discs. Draw their plans and end elevations. (5½ × 7½)

(3) Draw three views of a hexagonal prism lying with one of its rectangular faces on the HP and one hexagonal face ½ in. from VP and parallel to it. Length of prism ½ in., distance across flats of hexagon 1¼ in. (5½ × 7½) Nearest edge ½ in. from end VP.

(4) The prism of question 3 is turned round so that the hexagonal faces are vertical but inclined to the VP at 30°. Draw the plan of prism in this position with the nearest corner ⅜ in. from the VP and opposite corner ½ in. from end VP. From this view project the two elevations. (5½ × 7½)

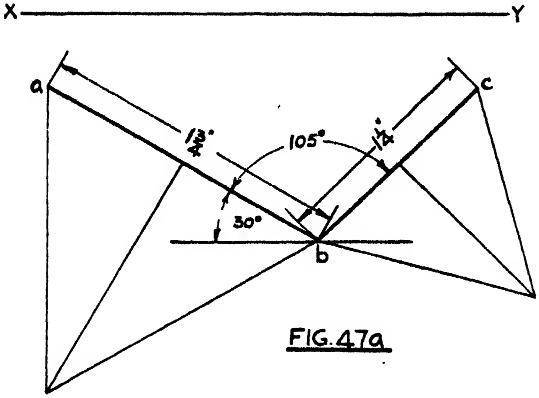


FIG. 47a

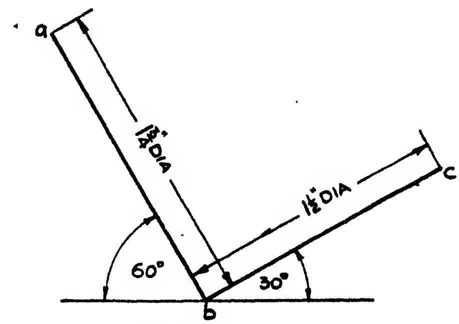


FIG. 47b

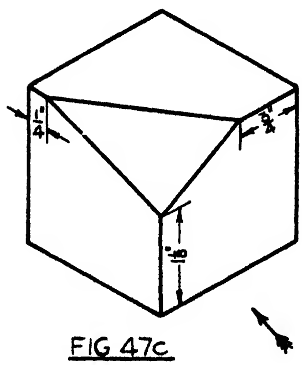


FIG 47c

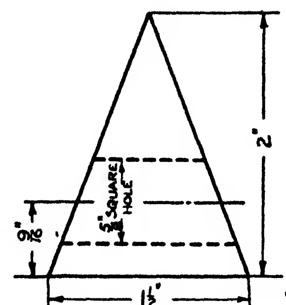


FIG. 47d

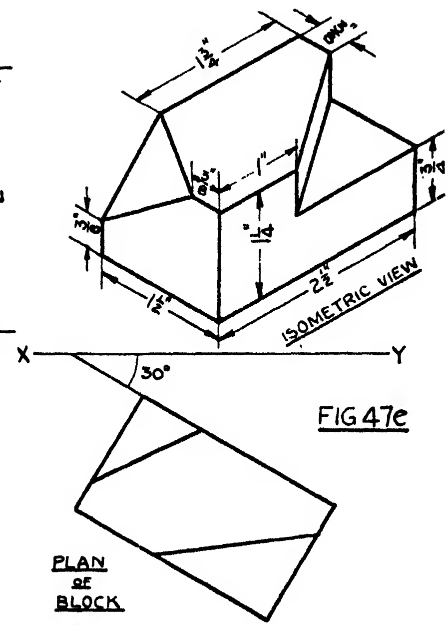


FIG 47e

(5) A rectangular block 2¼ in. × 1½ in. × ¾ in. is held with one of the large rectangular faces parallel to and ½ in. from the HP, and one of the smallest rectangular faces at an angle of 30° to the VP. The nearest edges are ¼ in. from the VP, and ⅛ in. from end VP.
Draw three views of the block in this position. (5½ × 7½)

(6) A cube having 1¾ in. edges has a corner removed as shown in fig. 47*c*. Draw an elevation looking in direction of arrow, and from it project the other two views. (5½ × 7½)

(7) The end elevation of a triangular prism pierced by a square hole is shown in fig. 47*d*. The axis of the hole is parallel to the triangular faces and midway between them. Draw the plan and elevation, if prism is 2 in. long and triangular faces stand parallel to the end vertical plane. (5½ × 7½)

(8) A pyramid has a hexagonal base 1½ in. across parallel edges, and stands with its base on the HP with one edge of base at right angles to the VP. Draw three views of the pyramid if perpendicular height is 2½ in. (5½ × 7½)

(9) The prism of question 3 is placed with one edge of a hexagonal face on the HP and perpendicular to VP, and a hexagonal face inclined at 30° to HP. Draw three views of the prism in this position. (Note the front elevation is obtained first by tilting the end elevation of question 3.) (5½ × 7½)

(10) The pyramid of question 8 is tilted about the edge perpendicular to VP until the base is inclined at 30° to HP. Draw three views of pyramid in this position. (5½ × 7½)

(11) The prism of question 7 is resting with one rectangular face on the HP and axis of hole parallel to HP. One longer edge of the base is at 60° to the VP, and nearest corner is ½ in. from VP. Draw three views of the prism in this position. (7½ × 7½)

(12) Fig. 47*e* shows a block and its plan. Copy this view and project the two elevations of the block in this position. ($7\frac{1}{4} \times 7\frac{1}{2}$)

(13) A cylinder $1\frac{1}{2}$ in. diameter $2\frac{1}{4}$ in. long is lying on the HP with the circular ends inclined at 30° to the VP. Draw three views of the cylinder in this position. ($7\frac{1}{4} \times 7\frac{1}{2}$)

(14) A hollow cylinder 2 in. outside $1\frac{1}{4}$ in. inside diameter is standing on the HP with its axis vertical and $1\frac{3}{8}$ in. from the VP. The top is cut off by a plane inclined at 30° to the horizontal, such that greatest height of the cylinder so cut is $1\frac{3}{4}$ in. Draw three views of the cylinder looking on to the inclined face in the end elevation. ($7\frac{1}{4} \times 7\frac{1}{2}$)

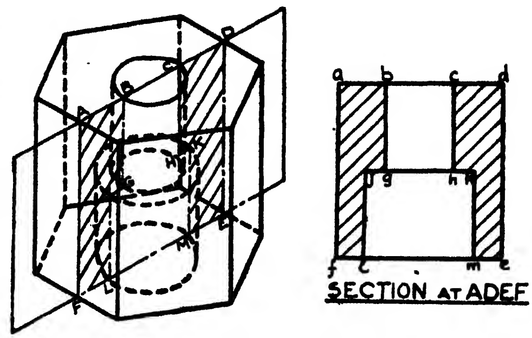


FIG. 48

SECTIONAL VIEWS

If any of the geometrical objects already considered were hollow, this fact could be indicated by the use of dotted lines to represent the hidden surfaces, but an intricate shape would be confusing if indicated by dotted lines. In such cases it is the practice to imagine that the object is cut and the front part taken away to reveal the internal structure. This process is called "taking a section on a plane" or "drawing a sectional view on a plane." Usually the object is shown as if cut by a flat surface (or plane) passing through its centre, but the plane may pass instead through any other part of the object. The cutting plane is generally parallel to one of the principal planes of projection.

When an object is shown in section, the fact is indicated by section lines or cross hatching; these lines are only drawn where the object is imagined to be cut by the section plane. Section lines are thin continuous lines, invariably sloping at 45°,[1] and to achieve neatness care should be exercised so that all the lines finish evenly at the edge of the surface, and the spacing is uniform. The spacing will vary a little according to the magnitude of the surface to be cross-hatched, but for the type of work shown in this book the spacing should be about $\frac{3}{32}$ in. to $\frac{1}{8}$ in. Untidy section lines will spoil a drawing which may be good in other respects.

In fig. 48 a hexagonal prism is shown in section, the section plane cutting the prism across the line AD down to EF. It is imagined, therefore, that the front half is removed, showing the surface ADEF. On this surface will be seen the full lines at the sides of the holes *bg*, *ch*, *jl* and *km*. Notice also that a full line would be seen from *j* to *k*, the elevation of the flat circular surface round the enlargement of the hole. The student will have noticed that when a tube is sawn lengthwise, not only is the cut surface seen, but also the farther rim, and hence lines such as *bc*, *gh*, *lm* must not be forgotten.

In making sectional views, certain rules are accepted and must be observed; fig. 49 illustrates some of these conventions.

Fig. 49*a*. Section lines inclined in opposite direction where two separate parts meet.

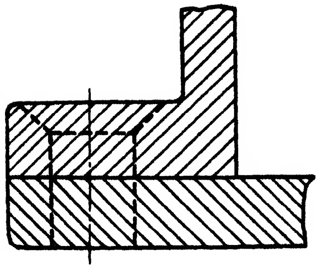
Fig. 49*b*. For a third part, one set of section lines at staggered pitch.

Fig. 49*c*. Shafts, keys, pins, screws, rivets or cotters shown in full.

An important point is illustrated in fig. 49*d* where the section plane passes across the bottom of the slot, but since it does not cut the surface at this portion, no section lines are shown at the slot.

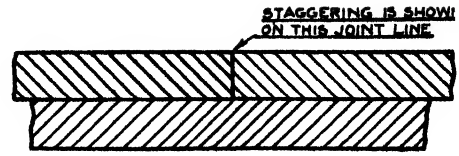
Conventional practice in sectioning of thin ribs is shown in fig. 50*a* which shows a cast bed plate with stiffening ribs. If section lines were shown where the plane

[1] Where the outline of section is inclined at about 45°, the slope of section lines may be altered to suit.—B.S. Spec. No. 308, 1943.



TWO DIFFERENT PARTS MEETING.
SECTION LINES INCLINED AT 45° IN OPPOSITE DIRECTIONS.

FIG.49a



3 PIECES OF METAL MEETING.
TWO SETS OF SECTION LINES MUST SLOPE IN THE SAME DIRECTION. THE PITCH IS STAGGERED ON THE MORE PROMINENT PART.

FIG.49b

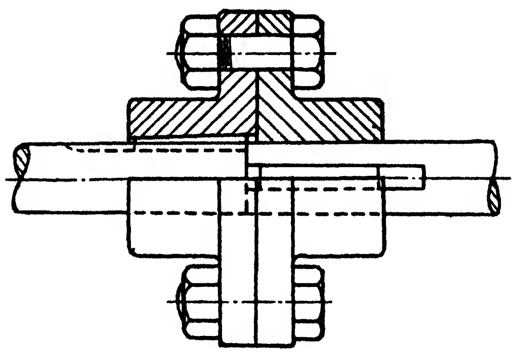


FIG.49c

WHEN SECTION PLANE PASSES THROUGH AXIS OF A SHAFT, BOLT, PIN, KEY OR COTTER THESE ARE NOT SECTIONED

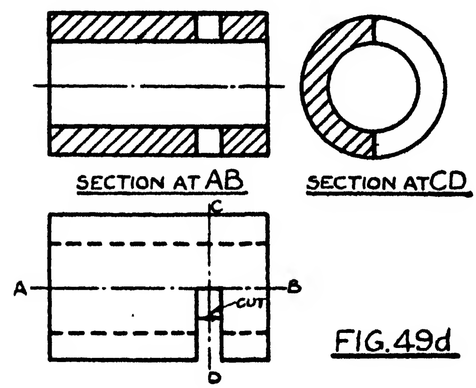


FIG.49d

passes through a thin rib, it would give a false impression of a large solid mass of metal. To avoid this erroneous impression, the rib is shown as if it were not cut by the plane, that is without cross hatching. The three ribs to the base plate are comparatively thin and therefore not shown in section, the rib from the boss to the central platform is much thicker, and as it constitutes a bulk of metal, it is shown in section. Judgment must be exercised to decide whether a false impression is given by cross hatching when section planes cut through such ribs. Does the front elevation of fig. 50*b*, for example, look like a casting only ¼ in. thick at any part? (Sometimes, instead of omitting cross hatching, alternate section lines are omitted where the plane cuts a thin rib.)

Attention is directed to the countersunk and counterbored holes shown in section in fig. 50*a*; notice the full lines seen where the conical part and cylindrical parts meet.

A further convention is shown in fig. 50*c*, in which the shape of the rib between the bosses is given by a revolved section. The section plane, after cutting through the component, is shown turned through 90° from its true position.

It should always be remembered that section lines are shown where the imaginary section plane would actually cut through material, and, therefore, the section lines must continue right across the

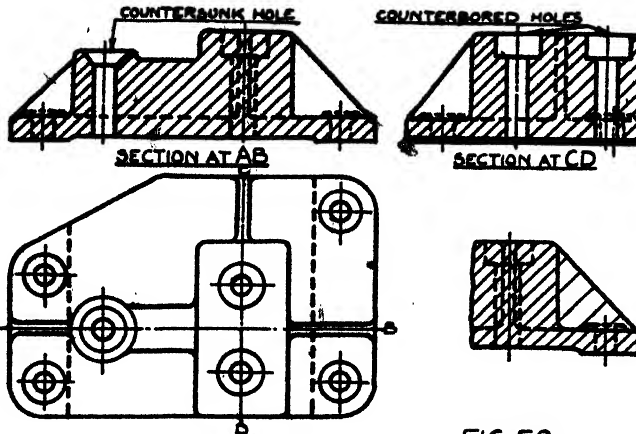


FIG. 50a

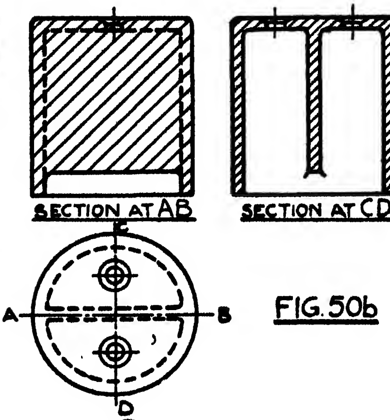


FIG. 50b

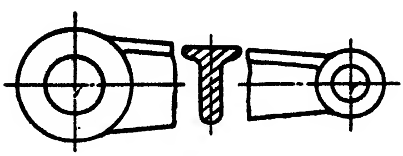


FIG. 50c

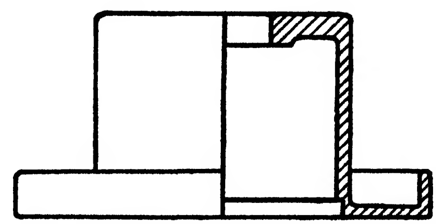


FIG. 51

surface from one full line to the next. Section lines can *never cross full lines*, except where alternate section lines are shown on a thin rib, as in fig. 50*a*. There must always be a change of direction or an alteration of pitch, as a full line indicates the end of one piece which is cut by the plane. Dotted lines, of course, are crossed by section lines, since they only indicate a surface hidden behind the plane.

PART SECTIONS

Part sections are sometimes given, and have the advantage of showing both the external and the internal appearance of the detail on one view. A half-sectional view of a flange plate is shown in fig. 51, and since it is a symmetrical object, all the particulars of the external appearance are shown on the left half of view and of the sectional appearance to the right of centre line. The dividing line between the half views is a full line in place of the centre line. Hidden lines between the cutting plane should be omitted unless essential for representation of object.

When showing sectional views it must be remembered that, whilst it has been imagined that part of the object has been removed to show a section, this is only a convenient device. The object has not actually been cut, and, therefore, the other views are not affected by the imagined removal of the part of the object.

Up to the early years of the present century, it was the practice to indicate the material of which the detail was made by varied types of section lines, such as alternate dark and light, or alternate full and dotted section lines. Owing to the immense variety of material in common use to-day, this practice is now obsolete. All metals (except white

metal) are shown by thin continuous section lines. Very occasionally a brass detail may have alternate continuous and dotted section lines, but this is not the common practice. Some draughtsmen now omit section lines, but this tendency is to be deplored; although it saves drawing time, the drawing is less clear and more likely to cause confusion and error. (*See also "broken section," fig. 65b, page 47.*)

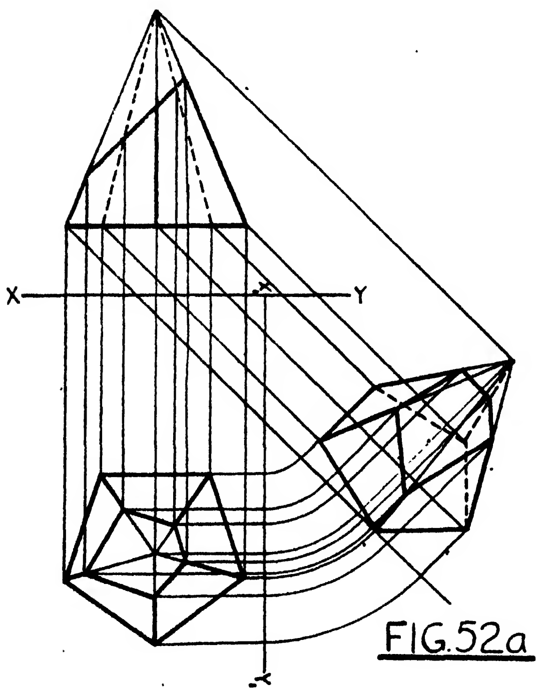


FIG. 52a

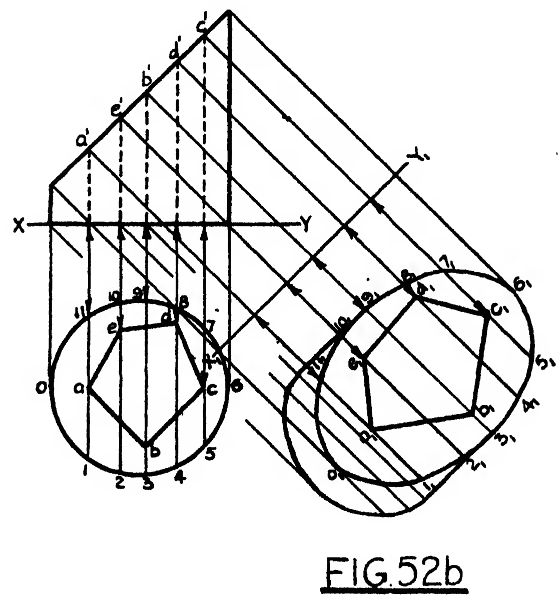


FIG. 52b

AUXILIARY PROJECTION

The pyramid of Example VI, page 32, is shown with the apex cut off by an inclined plane, which exposes an irregular inclined pentagonal surface. The true shape of this surface is not seen in any view shown in fig. 46*f* since the pentagon is inclined to all the planes of projection. To see the true shape of the surface it is necessary to view it in a direction at right angles or normal to it, and this can be done by making an auxiliary projection in the direction normal to the plane.

It is possible to project directly in a manner similar to the ordinary projection of an end elevation, as shown in fig. 52*a*, but it is not always possible to project an auxiliary view in a convenient position by this method.

An alternative usually adopted is to put in another XY line parallel to the inclined plane and project normal to this auxiliary XY. Since the positions of points in the plan relative to the first XY is known, positions of the point relative to the auxiliary XY may be plotted on the auxiliary projection fig. 52*b*.

Auxiliary projection is used very effectively in the drawings figs. 161 and 215, pages 126, 164.

EXERCISE VII

(1) **Give three views of the clamp (fig. 53*a*), full size.**

(2) **The Geneva stop plate in (fig. 53*b*) is $\frac{1}{16}$ in. thick and is pressed on to the bush shown. Draw three views, twice full size, of plate assembled on bush.**

(3) **The plan of a bolster for a die is shown in (fig. 53*c*). Copy this view and project the two elevations, half full size.**

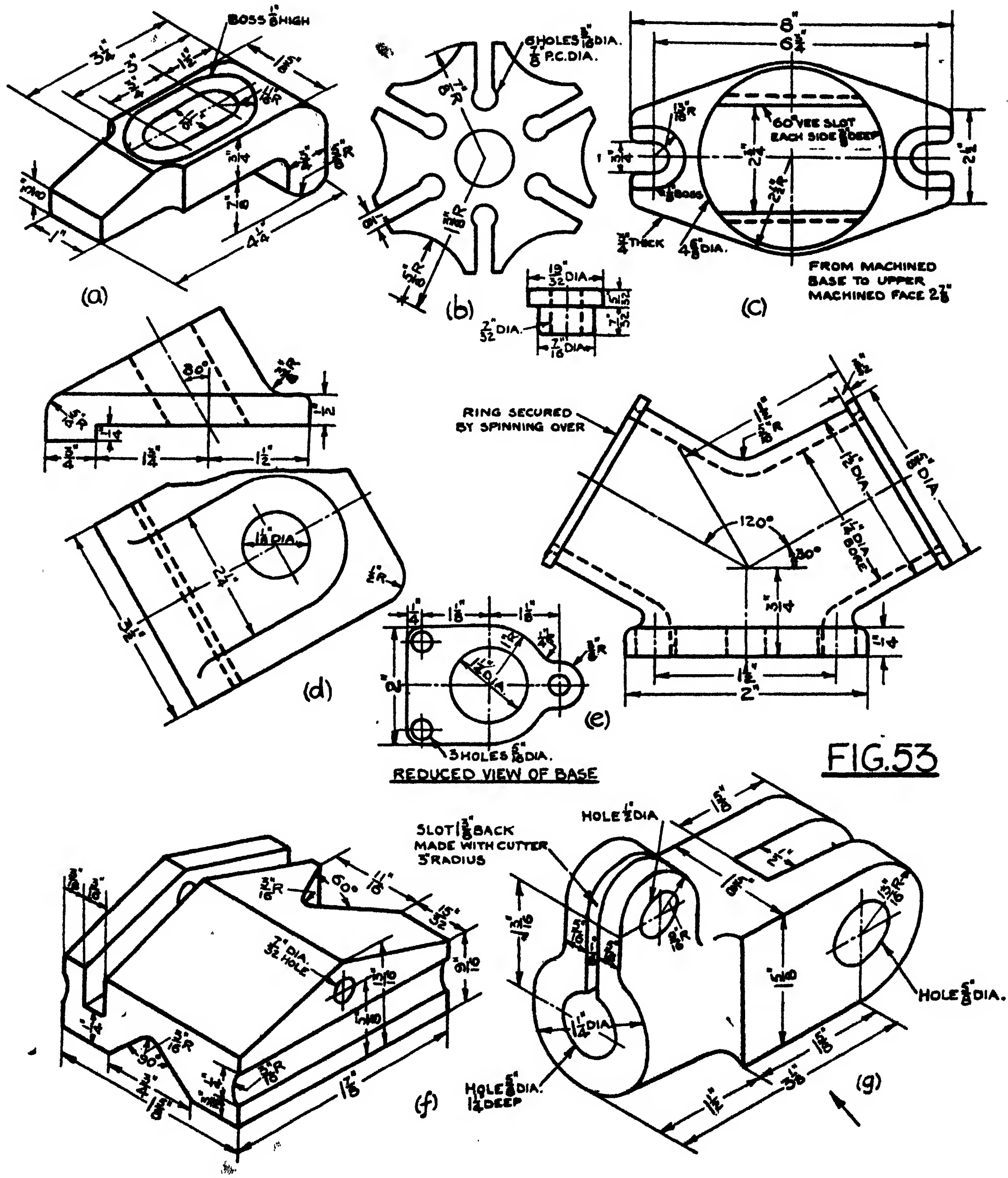

BOSS 1/8" HIGH
(a)
6 HOLES 3/16" DIA.
7/8 P.C. DIA.
(b)
8"
6 3/4"
60° VEE SLOT EACH SIDE 1/8" DEEP
THICK
DIA.
FROM MACHINED BASE TO UPPER MACHINED FACE 2 7/8"
(c)
19/32" DIA.
80°
(d)
RING SECURED BY SPINNING OVER
120°
30°
BORE
3 HOLES 5/16" DIA.
REDUCED VIEW OF BASE
(e)
SLOT 1 3/8" BACK MADE WITH CUTTER 3" RADIUS
HOLE 1/2" DIA
HOLE 5/8" DIA.
HOLE 3/8" DIA. 1 1/4" DEEP
60°
90°
(f)
(g)

FIG. 53

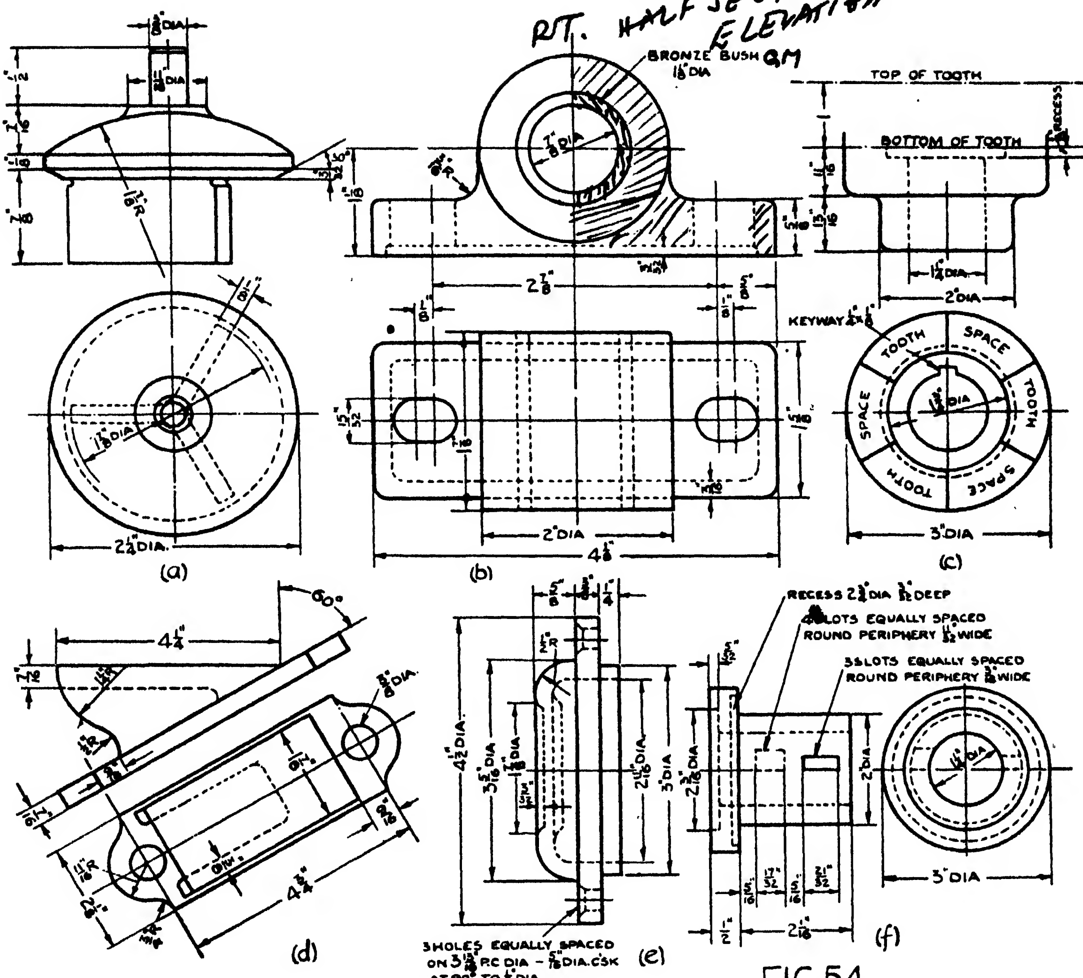


FIG. 54

(4) Copy the elevation and project a plan and end elevation of the angle mounting (fig. 53*d*).

(5) Copy the elevation and draw plan and end elevation of the carburettor feed pipe (fig. 53*e*).

(6) Give three views of the scribing block base (fig. 53*f*).

(7) Draw an elevation in direction of arrow and a plan of the rod end (fig. 53*g*).

(8) Draw plan, sectional elevation and full end elevation of the valve (fig. 54*a*).

(9) Copy the plan and project half sectional elevation and sectional end elevations of the bearing block (fig. 54*b*).

(10) Fig. 54*c* shows an incomplete drawing of a clutch collar. Make plan, elevation and sectional end elevation.

(11) Give an elevation in section on the centre line and project a plan and end elevation of the angle bracket (fig. 54*d*).

(12) Draw a plan looking on the recessed outer side of the end cover (fig. 54*e*) and project a sectional elevation.

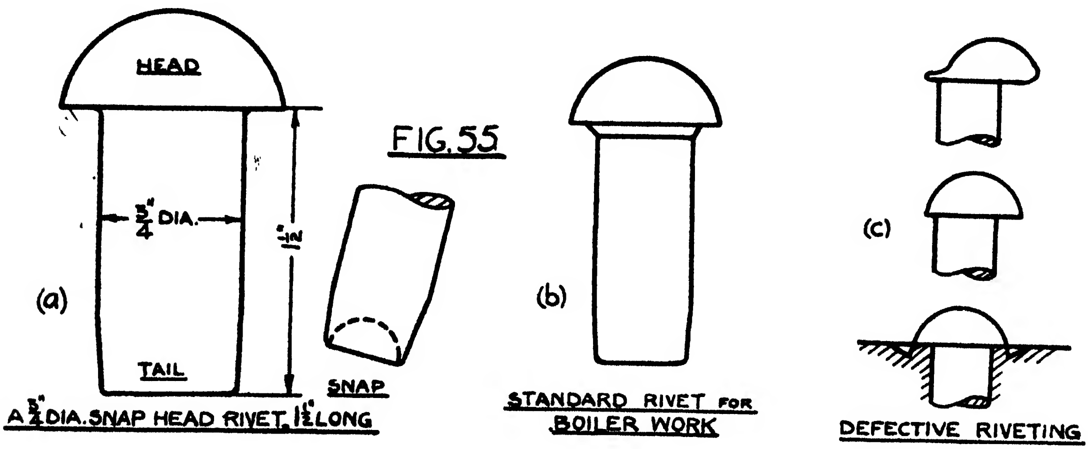
(13) Complete the two elevations of the sighting ring (fig. 54*f*) and give a plan in section on the centre line.

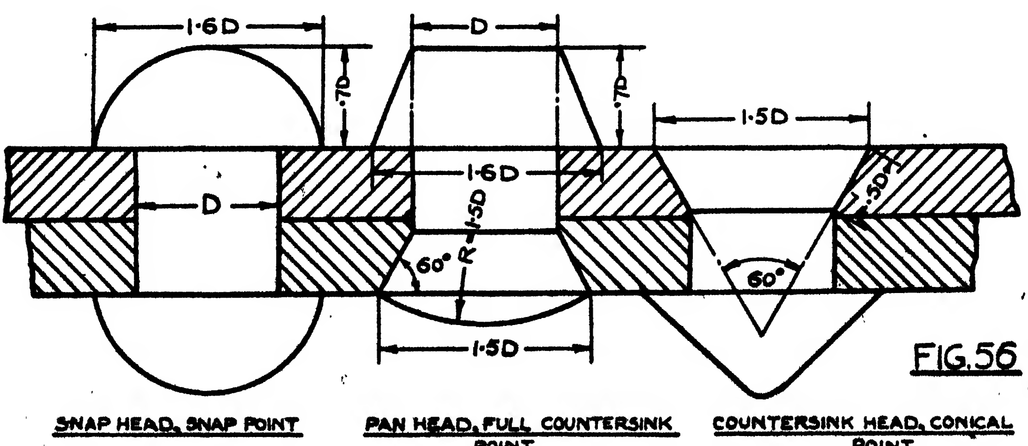
(14) The pyramid of question 8, Exercise VI, is cut by a plane inclined at 30° to HP passing through a point on the axis 1½ in. above the base. Make an auxiliary plan of the pyramid cut by the plane showing the true shape of the hexagonal face.

(15) Make an auxiliary projection of the hollow cylinder, question 14, Exercise VI, in a direction perpendicular to the inclined face.

FASTENINGS BY RIVETS, JOINTS AND SCREWS

THERE are various methods of joining parts of any structure or mechanism and the choice will depend upon factors such as the degree of permanency desired, the size and shape of the parts or the nature of materials. For a permanent fixing, parts may be welded, brazed together or secured by rivets. Welding is a process of increasing importance, and is discussed, with alternative methods, in Chapter X (see page 114). Structures and machine parts, when of welded construction, are known as fabricated constructions. In structural work, ship-building and boiler-making, welding is very much used as an alternative to





PROPORTIONS FOR RIVETS
(OVER ½ IN DIAMETER)

riveted construction. Brazing is a very strong method of securing parts when properly executed; it is used very largely in tubular work such as cycle and aircraft construction, for securing tool steel tips on shanks, and in many jobs when welding plant is not available. The parts to be secured must be clean when heated, and a brazing spelter (copper and zinc filings with powdered borax as a flux), applied to the junction on fusing, unites both parts. Soldering is a similar process, which when performed with care gives a very strong connection, but, of course, the joint is broken by heat.

RIVETS AND RIVETED JOINTS

Riveted joints are commonly used, principally in structural work, boiler work and ship-building. The size of rivets and number used in each joint are largely controlled by the practice of each industry, to conform to standards set by such examining bodies as the Board of Trade, Insurance Companies and Local Authorities. The student should become familiar with the standard types of rivets, joints and methods of riveting.

Rivets are made of mild steel with a head formed at one end and the tail slightly tapered, and are specified by the diameter of the shank. To make a joint, the rivets are brought to red heat and inserted in holes previously drilled in all the plates to be joined; the tail is then hammered or squeezed, using a snap, a hollowed tool, to form the shape of the rivet head. The holes should be drilled slightly larger than the rivets ($\frac{1}{32}$ in. to $\frac{1}{8}$ in. according to the size of rivet), and under the pressure the rivet fills out to the hole size. On cooling, the contraction in length tends to pull the plates together, so making a tight joint. A snap head rivet as used in general and structural work is shown in fig. 55*a*; for boiler work rivets having a chamfer formed under the head as in fig. 55*b* are used. Some effects of bad workmanship are shown at fig. 55*c*.

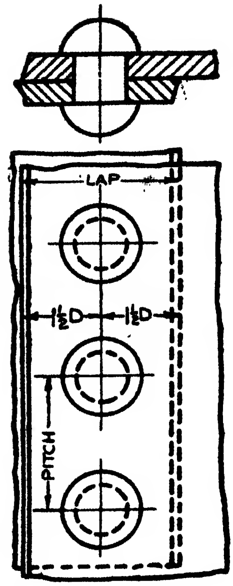
Snap heads are the most common, whilst panheads are sometimes used. For flush surfaces, a countersunk rivet must be used; in boiler practice countersunk rivets usually have a raised portion. The proportions given in fig. 56 apply only to rivets over $\frac{1}{2}$ in. diameter in accordance with the British Standards Institution Spec. No. 275. Rivets under this size are not in this proportion, but of the sizes shown in Table I from B.S.I. Spec. No. 641, page 169.

JOINTS

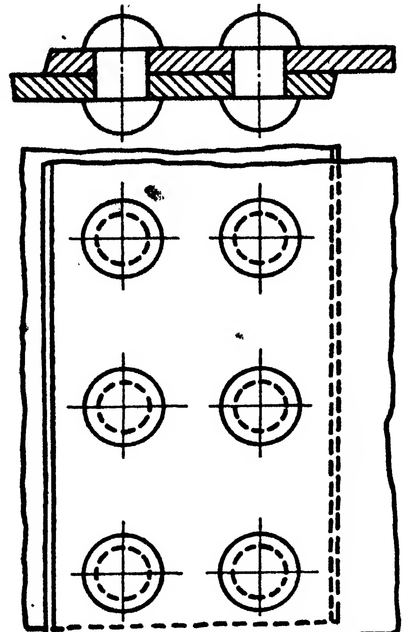
The simplest way to connect two plates by riveting is to overlap their edges and drill a row of rivet holes through both; when riveted this forms a single riveted lap joint (fig. 57*a*). If two or three rows of rivets are used the joint is called a double or treble riveted lap joint. When more than one row of rivets are used in a joint the rivets in all the rows may be in a line or the rows may have the rivets of one row spaced midway between those, or the next row; these forms are known as chain riveting and zig-zag riveting respectively. Fig. 57*b* shows a double riveted lap joint with chain riveting.

Where a joint is subjected to fluid pressure (*e.g.*, boiler work), the seams must be securely closed to prevent leakage. The closing must be performed carefully to avoid injury to the seams. Fig. 58*a* illustrates two methods by which the tool "jumps up" the edge of the seam to tighten the joint. Since fullering leaves a smooth surface along the edge, it has a neater appearance and is often used for external seams. Bad workmanship in caulking will produce a nick along the seam (fig. 58*b*) which will quickly lead to a failure.

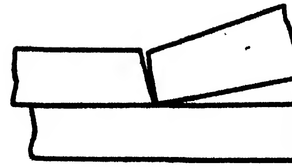
If a lap joint is subjected to a pulling force, since the plates are out of line, there is a tendency to pull into line; this gives rise to a weakness where the plates tend to bend (fig. 58*c*). There



SINGLE RIVETED
LAP JOINT
FIG. 57a

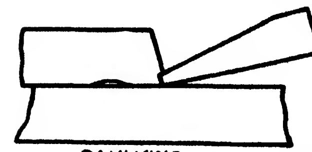


DOUBLE RIVETED LAP JOINT
(CHAIN RIVETING)
FIG. 57b



FULLERING

FIG. 58a



CAULKING

DEFECTIVE CAULKING

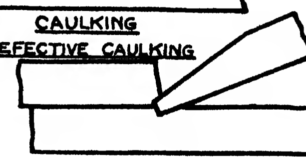


FIG. 58b

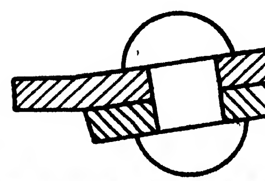
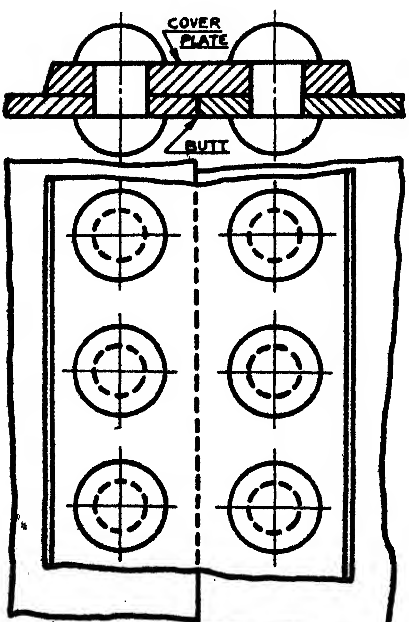
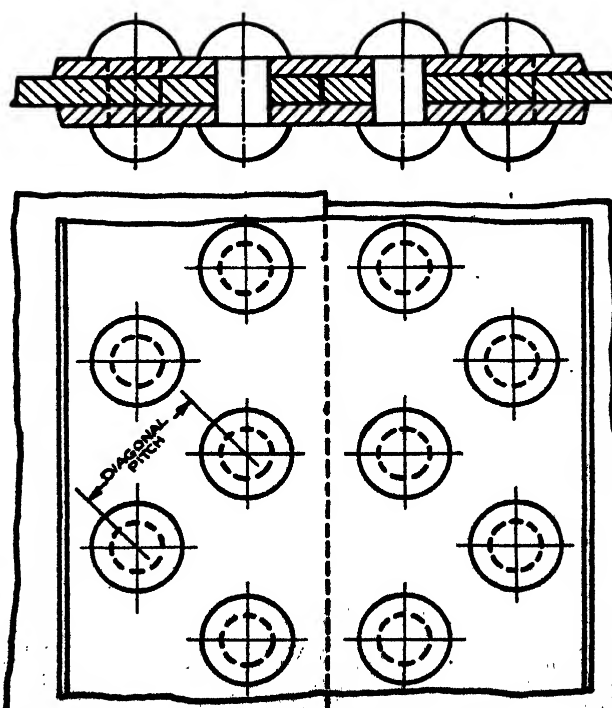


FIG. 58c



SINGLE RIVETED BUTT JOINT
(SINGLE COVER PLATE)
FIG. 59a



DOUBLE RIVETED BUTT JOINT (DOUBLE COVER PLATE)
(ZIG-ZAG RIVETING)
FIG. 59b

are, however, many satisfactory applications of the joint, such, for example, as the circumferential seams of a boiler shell.

A single riveted butt joint with single cover plate is shown in fig. 59*a*. The main plates are in alignment, and it will be observed that such a joint is, in effect, two lap joints. The more common form of butt joint has two cover plates, and fig. 59*b* showing two rows of rivets in each of the plates to be joined is therefore a double riveted butt joint with double cover plates zig-zag riveted.

Proportions of Joints. The pitch of rivets and distance from edge of plates are subject to the rules of examining bodies as mentioned before; too wide a pitch allows the plates to spring up

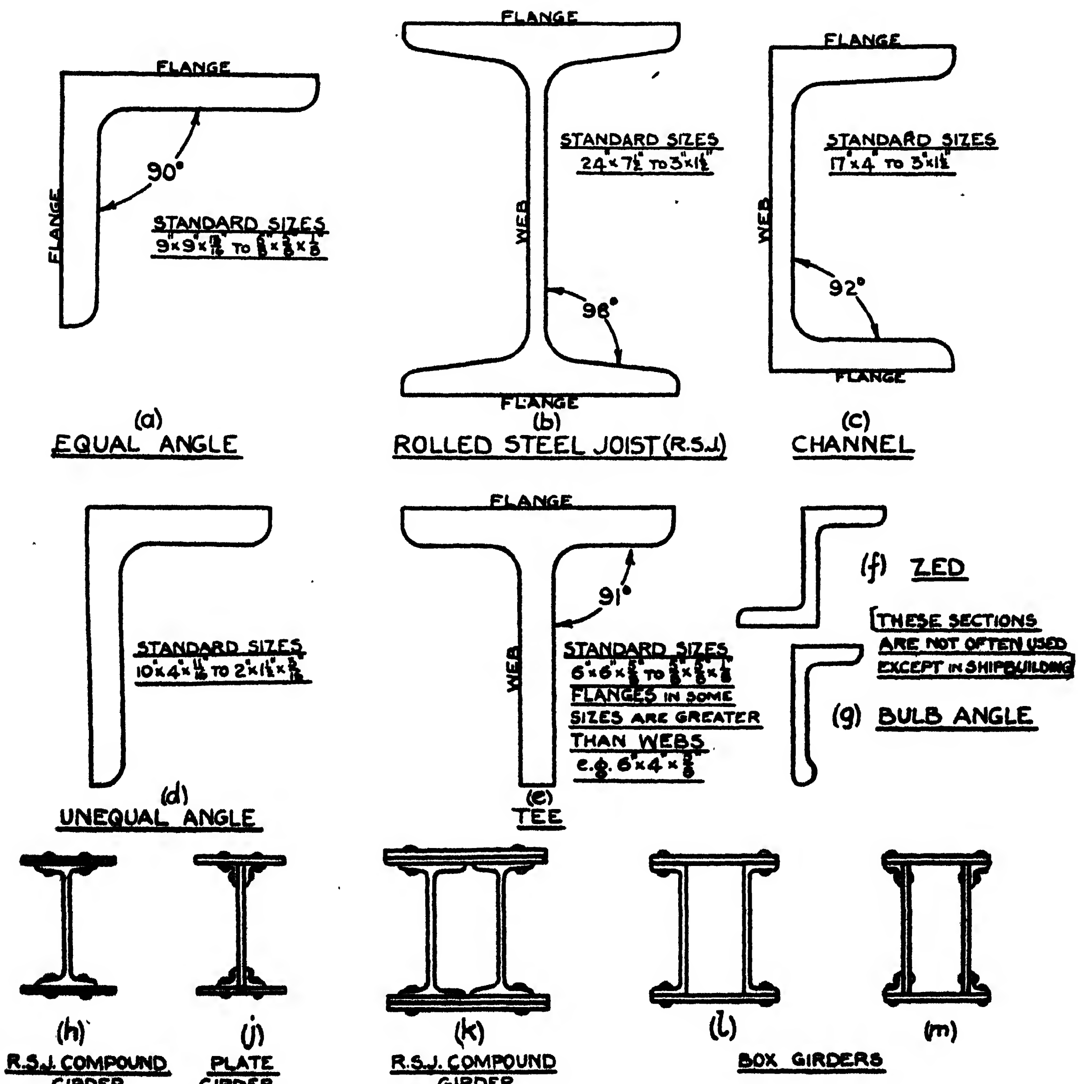


FIG. 60

between the rivets, and too small a pitch reduces the remaining plate area. The proportions in the examples shown are in accordance with good practice in structural or boiler work. The pitch is about $2\frac{1}{2}$ times rivet diameter and from the centre of rivet to edge of plate about $1\frac{1}{2}$ times rivet diameter.

Structural Work. In constructional work rolled steel sections are widely employed, and these sections are made in many standard sizes as shown in fig. 60*a-g*. Examples of the connection and application of rolled steel sections are shown in fig. 61, and the student should observe the methods used in

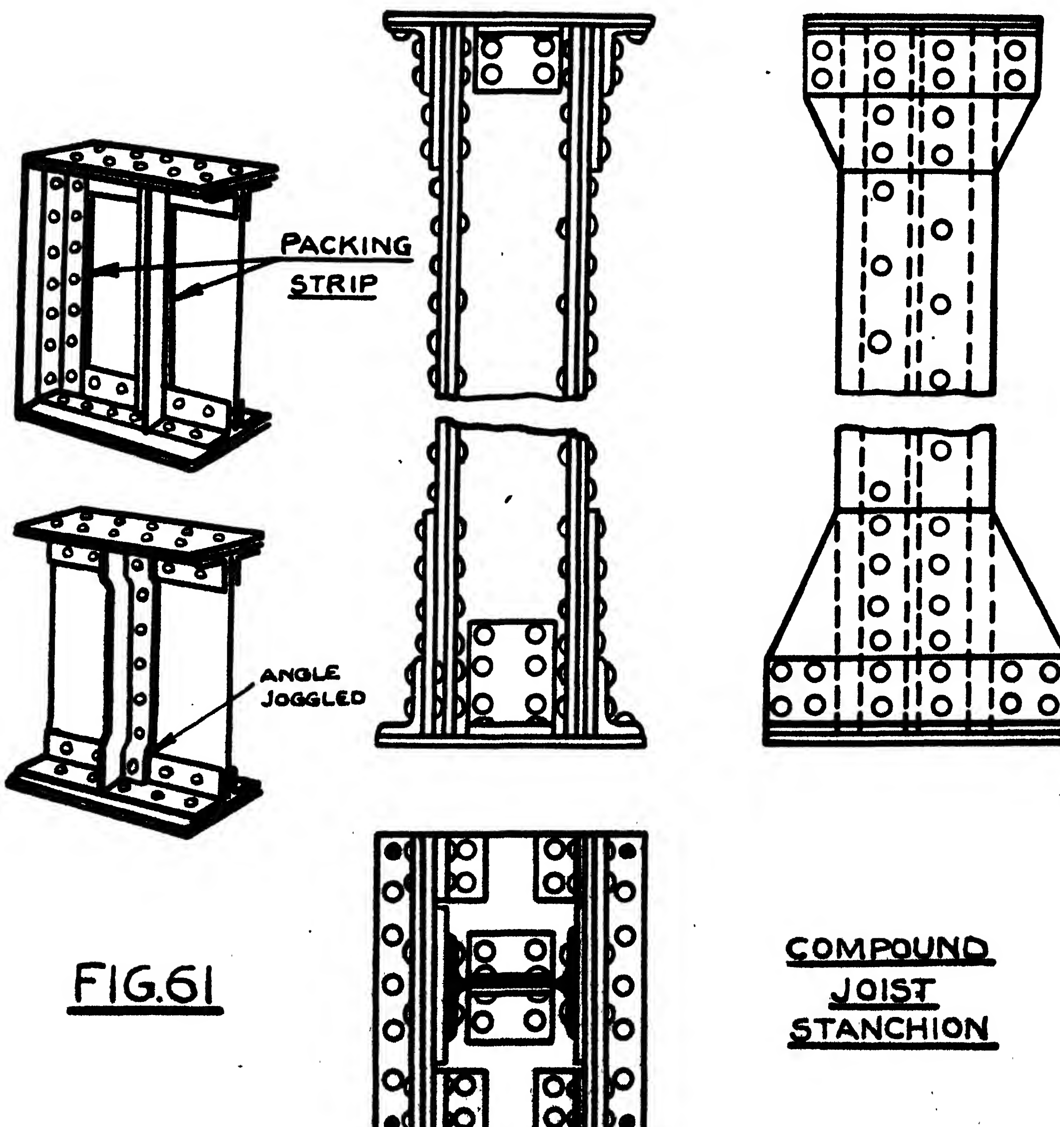


FIG.61

practice. For heavier work, the sections can be strengthened by riveting or welding plates to various rolled sections.

The compound girders, figs. 60*h* and *k*, frequently have two or more plates on each flange, and are made from the larger joists. In some cases two or three joists are used, a very large example, for instance, consisting of three 24 in. $\times 7\frac{1}{2}$ in. joists and plates 24 in. $\times$ $1\frac{1}{2}$ in. thick. For greater depths, plate girders such as fig. 60*j* are built up, for example, a 40 in. $\times$ $\frac{3}{8}$ in. plate web, with 4 in. $\times$ 4 in. $\times$ $\frac{1}{2}$ in. angles, and flanges of 12 in. $\times$ 1 in. plate. Large sizes of box girders are given on figs. 60*l* and *m*. Sections such as figs. 60*k*, *l* or *m* are used either as horizontal girders or vertical stanchions.

Boiler Work. Boiler making entails more plate work, whether riveting or welding is used. Angle sections are used sometimes, usually requiring forging to suit the boiler shapes. The difference in the type of work is illustrated by examples shown in fig. 62. Various methods by which tubes are secured to end plates are shown in fig. 62*a*. The designer has to consider the ease of construction in each case; for example, the angle section ring section (i) allows more tolerance in fitting and length of tube, but in all cases except (ii) the rivets are exposed to the fire, and example (iv) is not accessible for machine riveting. Fig. 62*b* shows methods of securing tubes and domes in vertical boilers. The turned ring of fig. 62*b* (i) is only used on smaller sizes, the tube being flanged out as at 62*b* (ii) for larger work.

To strengthen the end of a boiler, gusset stays as shown in fig. 62*c* are secured to the shell on long cylindrical boilers. Several such stays are spaced round the boiler end plate.

Light Gauge and Aircraft Riveting. An entirely different technique in riveting is used in light gauge work as in aircraft construction work where strength and lightness are required.

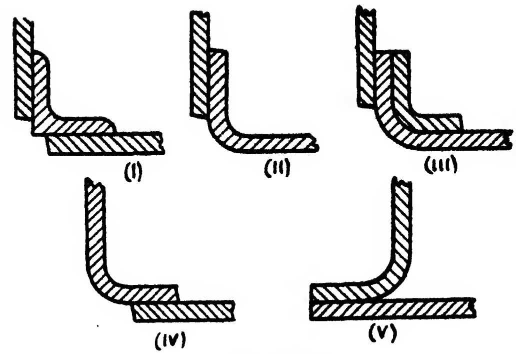


FIG. 62a

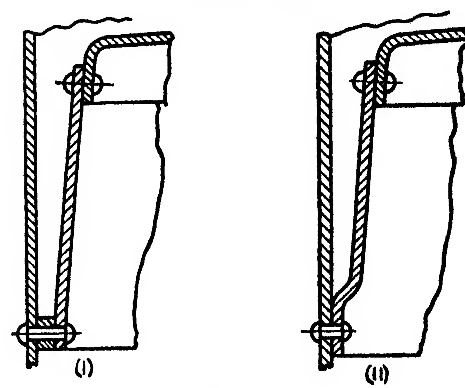


FIG. 62b

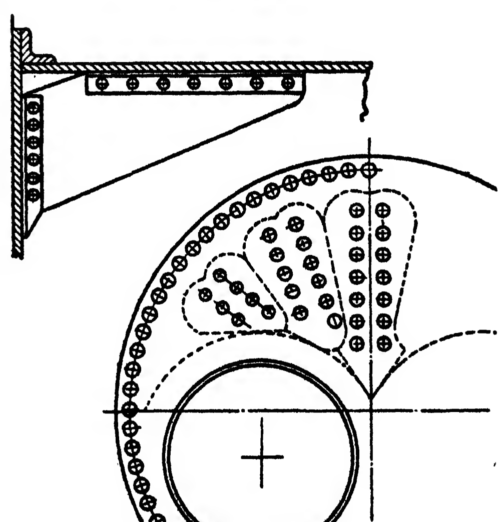


FIG. 62c

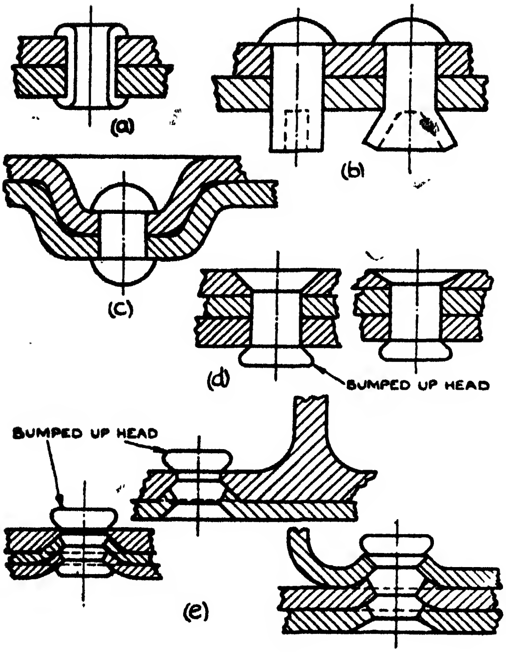


FIG. 63

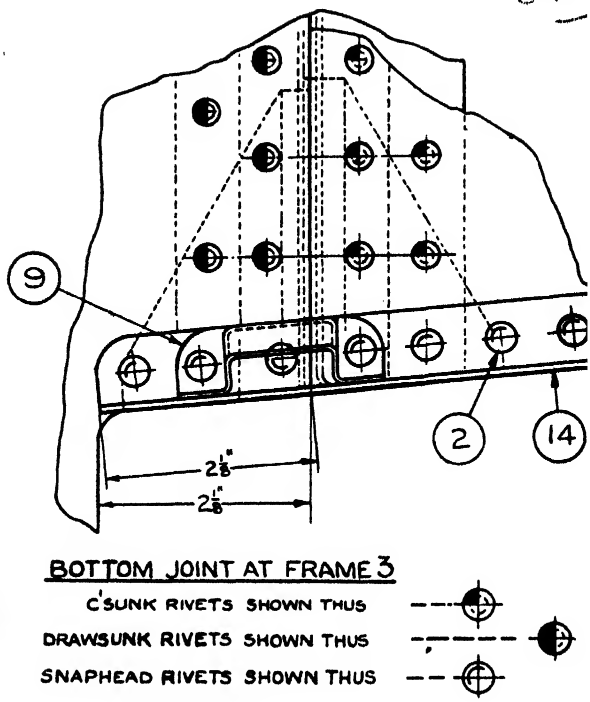


FIG. 64a

Various types of rivet are used as shown in fig. 63. The hollow rivet (*a*) gives a good grip over a larger clamping surface than a solid rivet of the same weight. The heads are formed by special tools. The conical rivets (*b*) are used for light tacking, the end being spread by a conical punch, whilst the patent dimpled rivet (*c*) is suitable for thin sheets subjected to a large pulling force, and is very suitable for floats and tanks. The rivet holds the recesses together, and the load is spread over the larger area. Fig. 63*d* shows simple countersunk rivets suitable for this class of work. Distinguish carefully the draw-sunk rivets of fig. 63*e*, which is similar in action to the dimpled rivet in spreading the load.

The application of these rivets is shown in fig. 64*a* which shows the assembly of a joint in the frame on an aircraft fuselage. The stiffeners, brackets and clips are detailed separately. A built-up section for a spar is shown in

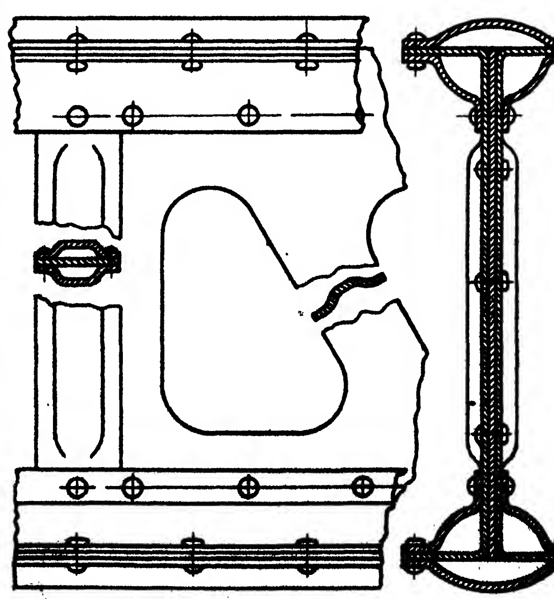


FIG. 64b

(*Figs. 63d, 63e and 64a by permission of Messrs. The Fairey Aviation Co. Ltd.*)

(8) Draw two elevations of the connection shown in fig. 66c. Scale one-eighth full size. (9 × 7)

(9) Draw plan looking on head of pin, sectional elevation, and half sectional end elevation of the knuckle joint shown in fig. 65a. Pin 1 in. diameter. (12 × 7)

SCREWS AND SCREW THREADS

The need for a fastening which would allow for dismantling and reassembling was realised very early in industrial design, and the plain pin was not a complete solution as it gave no tightening effect. By cutting a thread on the pin and using a corresponding nut this was overcome, but before screws could be commonly used and interchanged it was necessary to agree on standard shapes and sizes of thread. Pioneer work was done by Sir Joseph Whitworth, who introduced, in 1841, the standard shape of Vee thread which is still used in this country. The proportions of the profile are based upon the pitch or number of threads per inch, and consequently the Whitworth profile may be used on other than the standard diameter bolts. As an example, for a special purpose, a 2½ in. diameter bar may be screwed with eleven threads per inch of Whitworth profile, although a standard Whitworth bolt of 2½ in. diameter has only four threads per inch. The standard bolt would be used wherever possible.

The following definitions are important, and should be clearly understood (see fig. 67).

Pitch. The distance between corresponding parts of adjacent threads measured parallel to axis, *i.e.*, from crest to crest or root to root.

Full Diameter. The outside diameter of screw, measured normal to the axis over the crests of threads. This is now known as **Major Diameter.**

Core Diameter. The diameter of thread at the root measured normal to the axis. It is the full diameter minus double depth of thread. This is now known as **Minor Diameter.**

Effective Diameter. The length of a line drawn through the axis, at right angles to it, between the points where the line cuts the flanks of the thread.

VEE THREAD PROFILES

Fig. 68*a* shows the Whitworth standard profile. It has a Vee angle of 55° and is radiused at the crest and root. The radius at the crest renders the thread less liable to damage than one having a sharp Vee, whilst a sharp Vee at the root seriously weakens a screw. This thread, which is used generally on all English

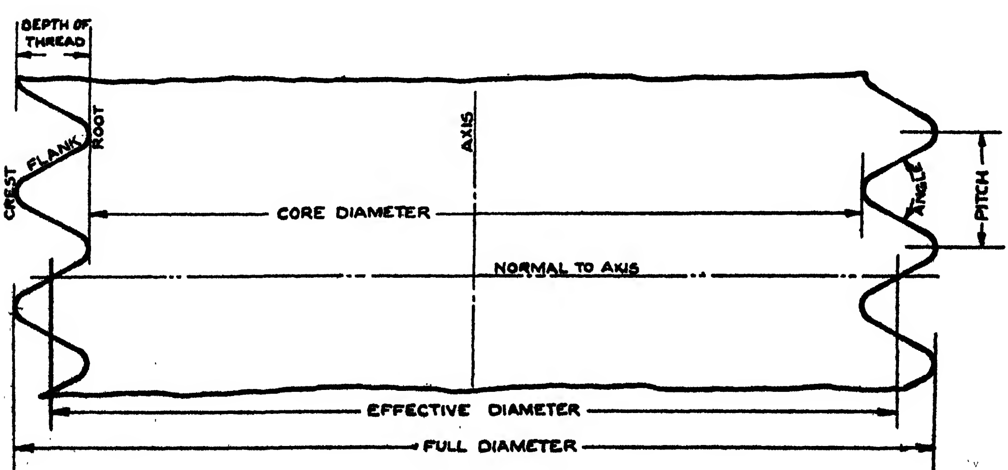


FIG. 67

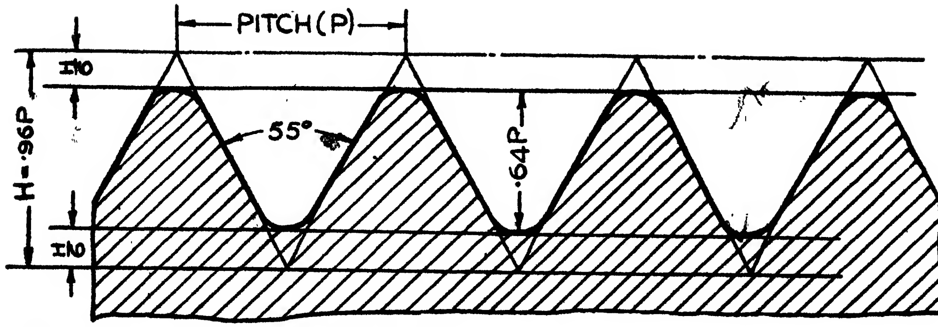


FIG. 68a WHITWORTH (B.S.W.)

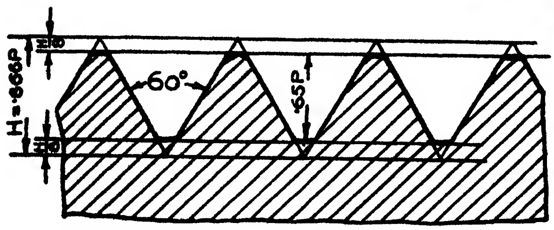
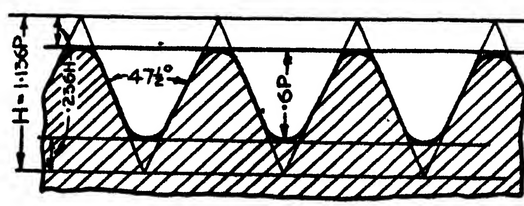


FIG. 68b SELLERS (U.S.A.)



BRITISH ASSOCIATION (B.A.) FIG. 68c

work, should be compared with the American standard, the Sellers. Note that the Sellers (fig. 68*b*) has a 60° angle and flats at crest and root. In comparison, the Whitworth has a slightly greater core diameter, and the absence of sharp corners at the root also makes it a little stronger, but the Sellers is easier to produce with absolute accuracy and the wear is more uniform since the friction is the same at all parts of the profile. The Whitworth is liable to wear excessively at the curved root and crest.

For instrument work, small screws are made to conform to the British Association standard. They are designated by numbers, No. 0BA being the largest (0·236 in. outside diameter) down to No. 25 (0·0098 in. diameter). Nos. 0 to 12 (0·0511 in. diameter) are used commonly. The profile is shown in fig. 68*c*. The proportions of the screw are based on a formula worked out in millimetres, and this gives rise to the odd diameters. A thread having flats at top and bottom, and angle 53° 8′, the Lowenherz thread, is used for instrument work in other countries. Particulars of some B.A. screws are given in Table V, page 172.

REPRESENTATION OF SCREW THREAD

The correct projection of a screw thread, even when the radii at root and crest is omitted, is tedious, and the curves take a long time to fill in neatly. An approximation is obtained by drawing straight lines instead of curves, as in fig. 69*a*, where the threads are drawn at 60° to enable the use of a 60° set square; screws are rarely shown in this way in practice, but it suggests a good quick method of representation. Notice that each thread is shown by a sloping line right across the screw at the crest and a shorter sloping line at the root. To represent a thread therefore, mark off the pitch evenly, and approximately to scale, on one side of the screw; for example, in drawing a 1½ in. Whitworth screw which has seven threads per inch,

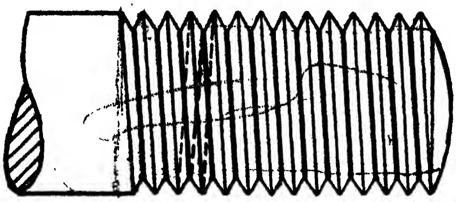


FIG. 69a

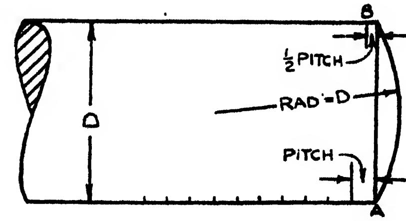


FIG. 69b

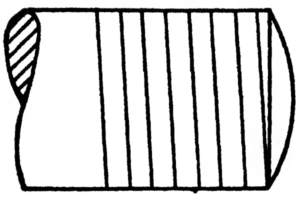


FIG. 69c

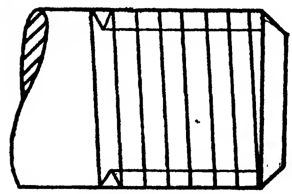


FIG. 69d

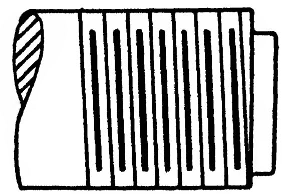


FIG. 69e

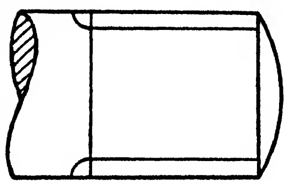


FIG. 70a

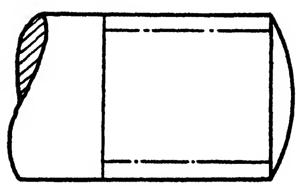


FIG. 70b

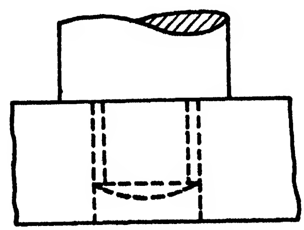


FIG. 70c

mark off on one side equal spaces of ⅛ in. plus a little bit, and on the other side mark off one distance of half this pitch. (Note that since the thread advances one pitch in one revolution, it advances half a pitch in half a revolution from A to B (fig. 69*b*).) Join opposite marks by a line sloping half a pitch in the half-revolution and then draw parallel sloping lines from each of the previously marked pitch lengths (fig. 69*c*). These lines represent the crests of successive threads. Using a 60° set square draw a triangle very faintly on each side of the screw to represent a Vee profile; this will give the approximate depth of thread. Through the apex of the Vee draw very faint horizontal guide lines (fig. 69*d*). Finally, midway between the sloping lines, draw short darker parallel lines to correspond with the lines at the root of the thread (fig. 69*e*). This method of representation is speedy and it gives the appearance of a thread.[1] It is essential in drawing screw threads that all the lines should slope at the correct angle (*i.e.*, ½ pitch in diameter of screw), that lines should be evenly spaced, and end crisply at the outside or guide lines. The guide lines should be so faint that they are not apparent on completion of the drawing.

Other methods of representing a thread are sometimes used (figs. 70*a*, *b*), being quicker to draw, but they are liable to misinterpretation as they are not suggestive of a screw. A further method is to draw lines similar to those of fig. 69*e* but perpendicular to the axis instead of sloping; this method is very little quicker, and not so effective.

[1] The new B.S. Spec. No. 308, 1943, recommends the use of fig. 70*a* normally, and fig. 69*e* only where necessary for clarity and appearance.

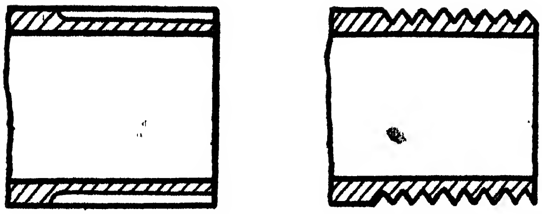


FIG. 71a – SECTION THRO' A PIPE

The threads shown in figs. 69*a* and 69*e* are both right-hand (R.H.). That is to say, such a screw turned in a clockwise direction would enter into a nut. To cut such a thread a tool starting from the right-hand end would travel to the left while the bar turned in an anti-clockwise direction, on to the tool. This gives, as shown for an R.H. thread, a slope upwards to the left when the axis is shown horizontal.

To draw a left-hand (L.H.) thread by the method of fig. 69*e*, the lines would have the same inclination (½ pitch in the diameter) but in the opposite direction. Only by this method or by the full thread (69*a*) can this distinction be shown; when the other methods are used a left-hand thread must be indicated by the letters L.H. If no note is made *a right-hand thread is assumed*, so it is safest to specify L.H. whatever method is used for such a thread.

The method of representation shown in fig. 69*e* is confusing for showing screws which are hidden, and therefore such threads should be shown as indicated in fig. 70*c*.

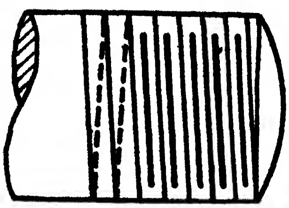
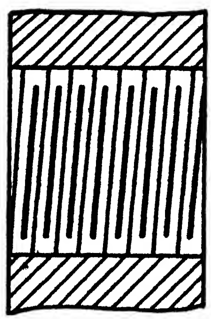


FIG. 71b



SECTION THROUGH A RIGHT HANDED NUT

SECTIONAL VIEWS OF SCREWS

In taking a section on a plane which includes the axis of a screw, the bolt is left in full as previously stated (page 34), unless it is necessary to show some hidden detail in the bolt itself. When a section is taken, for example, on a pipe detail, the section shows the screw profile (fig. 71*a*).

The complete helix is represented in fig. 71*b* by the full sloping line and the dotted line showing the slope of the threads at the back of the bolt. It is these back threads which engage that portion of a nut which is seen in a sectional view. Hence, the threads in a right-hand nut shown in section will slope in the opposite direction to the thread on a right-hand bolt (fig. 71*b*).

The lines for crest and root are often omitted on threads of large diameter and

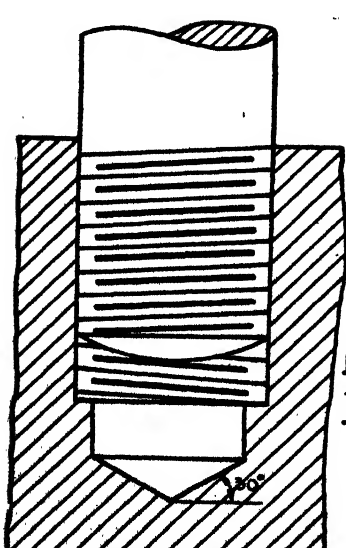


FIG. 71c

small pitch, and thread represented by the Vees only, as in fig. 103*c*, page 81.

Blind Tapped Holes. Fig. 71*c* shows a blind hole with screw. Note the clearance for incomplete thread on the tap, and extra depth of drilled hole, clearance for the chip from the tap.

B.S. WHITWORTH, B.S. FINE AND B.S. PIPE (PARALLEL) THREADS (Tables II, III, IV, pages 170, 171).

A British standard Whitworth screw (B.S. Whit.) thread has a Whitworth standard profile of thread, and the stipulated pitch for the particular diameter, *e.g.*, 1 in. screw $\frac{1}{8}$ pitch or 8 threads per inch. The Whitworth profile is also used on other standard threads, the B.S. Fine and B.S. Pipe. For a given diameter, a British Standard Fine (B.S. Fine) thread has a finer pitch. Since the proportions are based on the profile, a B.S. Fine screw has a smaller depth of thread and a larger effective and core diameter than a corresponding B.S. Whit. screw, and is therefore stronger in tension for a given weight of bolt. The B.S. Fine is used extensively in aircraft work. The American National Standard Coarse and Fine correspond with B.S. Whit. and B.S. Fine respectively.

For gas, steam and water piping, a thread of Whitworth profile, the British Standard Pipe (B.S. Pipe) thread is used. It is specified by the bore of the pipe, the outside diameter of the thread being slightly less than the rough outer diameter of the pipe. Thus a 1 in. B.S. Pipe thread is 1·309 in. diameter. The thread is almost identical with that known as a gas thread. There are various other standards used in particular branches of industry, such as the "brass" thread, optical thread, etc., details of which can be found in reference books on screw threads.

TRANSMISSION SCREWS (LEAD SCREWS, ETC.)

Vee threads are subject to fairly large frictional forces which are advantageous when the screws are used for clamping parts together, but when it is required to transmit a movement by means of a screw, as in the lead screw of a lathe, the friction must be reduced. This is achieved by making the surface taking the thrust perpendicular to the thrust, so avoiding oblique outward forces.

Square Threads. A square thread (fig. 72*a*) has this advantage, but it is sometimes difficult to manufacture on a lathe owing to the swarf clogging between the wide tool and parallel sides of the thread, and it is also comparatively weak at the root as the width of thread at root is only half the pitch. Square threads can now be produced more easily by a milling process.

It is always necessary to provide a recess as in fig. 84*e*, or a small hole as in fig. 84*a*, to allow space for the tool when cutting a thread.

Acme Thread. The acme thread (fig. 72*b*) is a modification of the square thread, and in addition to being easier to cut and stronger at the root, it has the advantage of easy engagement with sliding half nuts, and is very satisfactory for transmission of axial motion.

Buttress Thread. When the thrust is transmitted in one direction only (for example, by a vice screw) the buttress thread is sometimes used. The form of thread is not standardised, but is usually as shown in fig. 72*c*.

There is no conventional representation for a square or acme thread; a short thread of three or four turns is drawn in full using straight lines instead of curves, whilst a longer thread is shown by two or three threads at each end and chain lines between, at full and root diameters (fig. 72*d*).

MULTIPLE THREADS

Since the depth of a thread is dependent on the pitch, a large pitch, giving a great axial movement in one turn, would entail a deep thread. This can be avoided by cutting more than one thread on a bar, all equally spaced round the

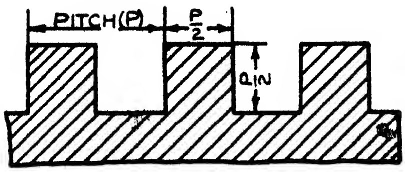


FIG. 72a - SQUARE

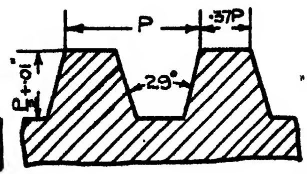


FIG. 72b - ACME

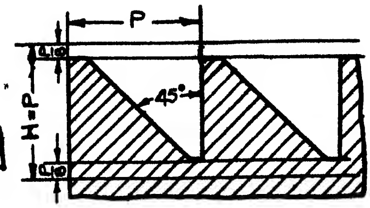


FIG. 72c - BUTTRESS

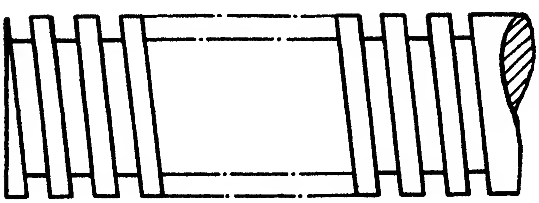


FIG. 72d

bar. Thus a two start thread may have a thread moving a distance of ½ in. in one revolution of the bar, but ¼ in. behind this have another thread cut; the pitch (distance between threads) is ¼ in., but the thread advances twice this distance in one revolution. The advance of thread per revolution is called the lead. For a three start thread the lead is three times the pitch, and the threads begin at points 120° apart on the circumference of the screw.

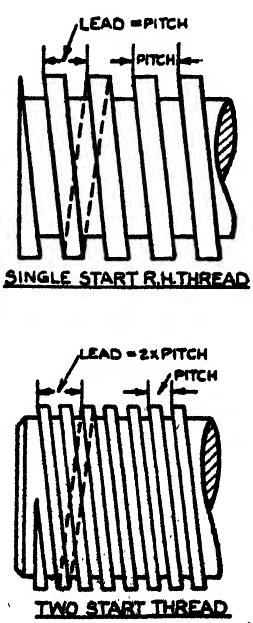


FIG. 73a

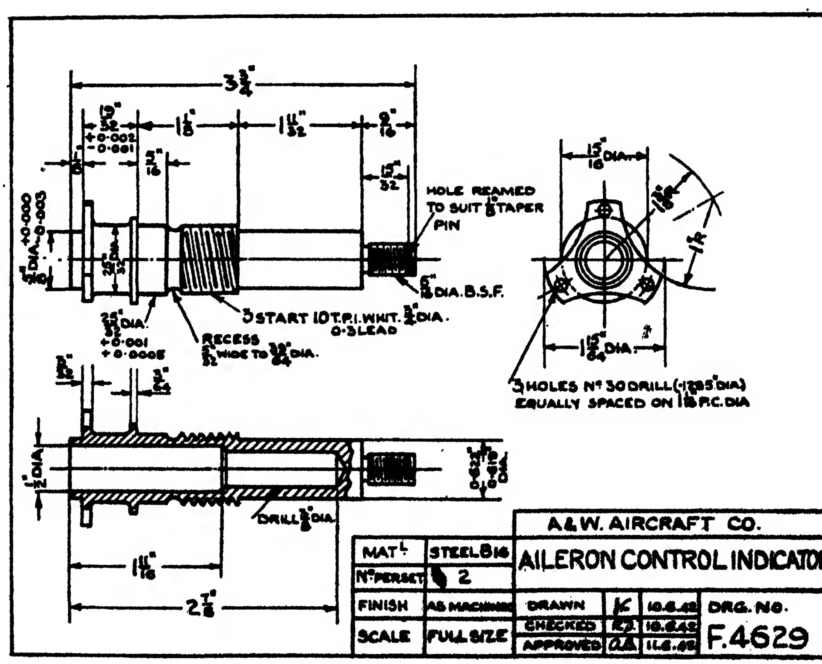


FIG. 73b

To show a multiple start thread, the slope of the lines is determined by considering the movement of the thread in half a revolution as before, and the thread is then represented in a manner similar to the single start thread. A two start square thread is shown in fig. 73*a*, the dotted lines showing the movement (the lead) in one complete revolution. A detail having a three start Vee thread is shown in fig. 73*b*; the thread is also seen in section in the plan. In American practice the terms pitch and lead are interchanged with the English practice.

STANDARD NUTS AND BOLT HEADS

The hexagonal nut and bolt head is the most usual in modern work. The proportions have been standardised for the different diameters of B.S. Whit. and B.S. Fine bolts as in Tables VI–VII, pages 172, 173. A square head of the same width across the flat faces is bigger than a hexagon across a diagonal, and not only requires more space, but needs a quarter of a turn to bring it into the same position for a spanner, whereas a hexagon needs only one-sixth of a turn. An octagon would only require an eighth of a turn, but there would be more liability for the spanner to slip round the corners of the nut or bolt.

Black bolts and nuts, which are used for rougher types of work, particularly where exposed to the atmosphere, are forged, and machined only at the thread and face of nut. Bright bolts and nuts are machined very accurately from bright drawn bar, which itself conforms to close limits of size.

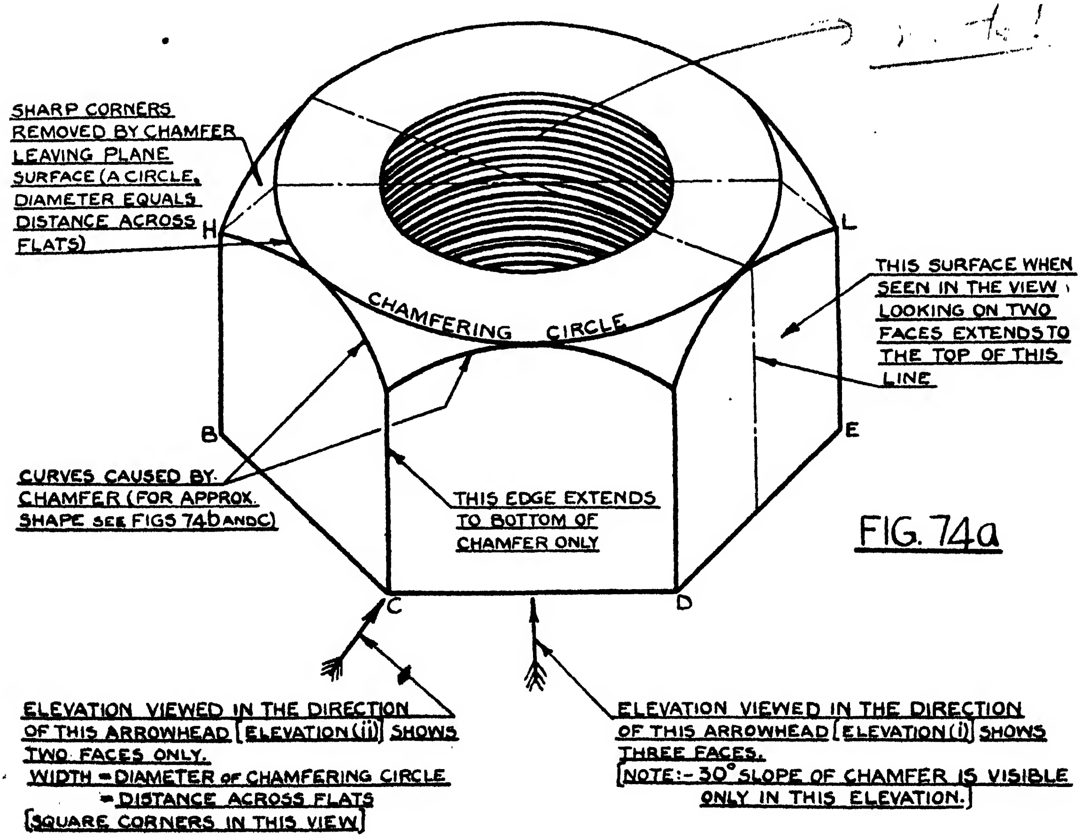


FIG. 74a

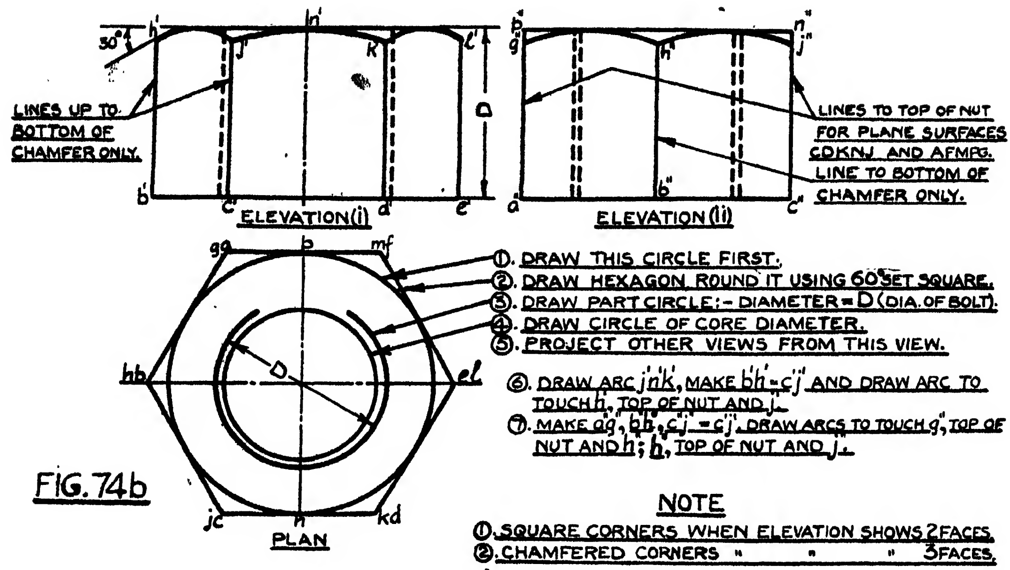


FIG. 74b

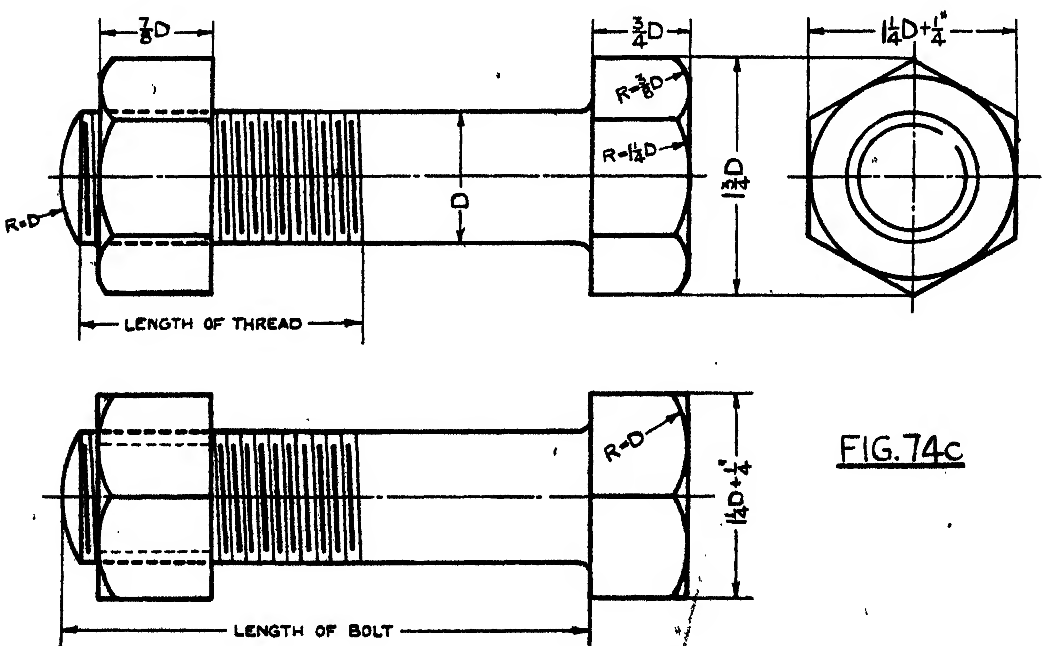


FIG. 74c

DRAWING OF NUTS AND BOLT HEADS (Figs. 74*a*–74*c*)

All nuts and bolt heads on a drawing should be drawn very neatly; carelessly drawn they would spoil an otherwise good drawing. The student should remember also that in looking at a hexagonal prism, if three faces are seen in the elevation, one face being parallel to the VP, only two faces can be seen in the end elevation. This elementary fact is often overlooked even by experienced draughtsmen.

In a drawing office, charts such as in Tables VI and VII are available, and these should be referred to in order to determine the distance across the flats, to enable the chamfering circle in the plan to be drawn.

As a guide, the proportions given in fig. 74*c* may be used. These proportions approximate to the dimensions given in British Standard Spec. No. 1083, which supersede the specifications formerly used for B.S. Whit. bolts and nuts during the war period. It is probable that the use of this specification will be continued after the war also. Formerly the proportions were as follows:

Distance across flats	$= 1\frac{1}{2}\,D + \frac{1}{8}''$
Distance across corners	$= 2\ D$
Depth of head of bolt	$= \frac{7}{8}\ D$
Thickness of nut	$= D$

Bolts and nuts to these proportions (or to Table VI) will probably become known as the B.S. Whit. (large hexagon) and have a limited application, while those to the proportions given in fig. 74*c* (table VII) are now used and will probably continue in use, known as the B.S. Whit. (small hexagon).

Since the proportions given are only approximate however, it is most desirable that students should form the habit of referring to Table VII or similar charts when drawing the nuts and bolts now known as B.S. Whit. (small hexagon), and which will probably become known generally as the Whitworth bolt.

The sharp corners are always taken off one side of a standard nut by a chamfer, which produces a curve at the top of all the faces and leaves a flat circular top to the nut, of diameter equal to the distance across flats of the hexagon. The view looking on this flat circular face should be drawn first, by describing a circle of diameter equal to the distance across the flats, and drawing tangents with a 60° set square to form a hexagon. The other views can be projected from this one.

Study the construction and proportions of the nut and bolt head shown in figs. 74*a*, *b* and *c*.

Bolt Ends. The end of a screw is not left flat, as it would then easily be damaged. Various ways of finishing the ends are shown in figs. 69*a*–69*e*, the rounded end being that most commonly used.

ALTERNATIVE BOLT HEADS

(*a*) **Square head** bolts are used principally in positions where the head is prevented from turning whilst the nut is tightened by a face on the work. Examples of this are shown on the coupling, page 98, and the bearing, page 88. They are often used for a similar reason in the Tee slot of a machine table. Standard square head bolts are usually black bolts. The usual proportions are shown in fig. 75*a*.

(*b*) **Cheese Head.** The most common head when use of spanner is not satisfactory. Usually in smaller sizes only, as a screwdriver does not give sufficient clamping effect with large-size screws (fig. 75*b*).

(*c*) **Round Head.** Avoids the sharp edges of the cheese head, but the screwdriver slot is more easily spoilt. Used in preference to cheese head for appearance only (fig. 75*c*).

(*d*) **Countersunk.** Used where the head must not project above surface. Care must be exercised in using these, as the conical head

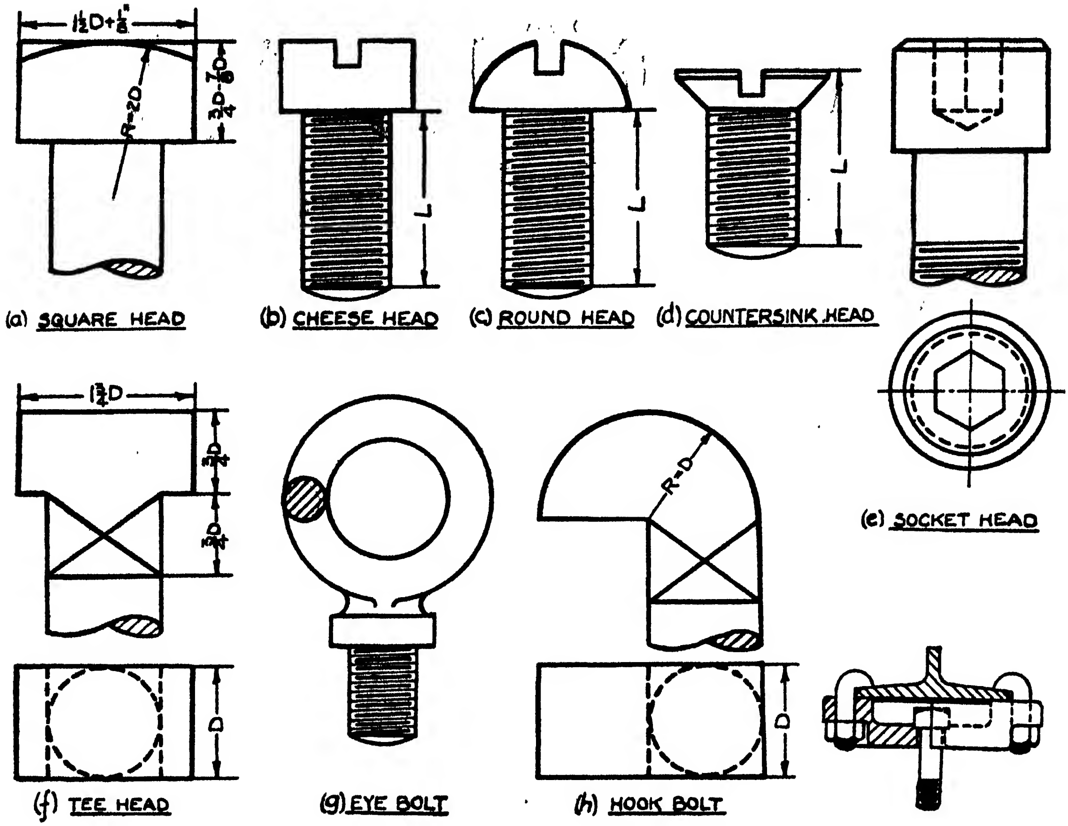


FIG. 75

acts as a locating point, allowing no clearance, even though a clearance is made in the plain hole. This demands great accuracy in position of holes (fig. 75*d*).

(*e*) **Socket Head Cap Screw.** Used in place of a cheese head and can be very effectively tightened by means of a hexagonal wrench instead of a screwdriver. Used largely on machine and tool work. On account of the difficulty of obtaining a clearance with a countersunk screw, this type is often used in a counterbored hole for a flush surface (fig. 75*e*). Socket head screws are sometimes known as Allen screws.

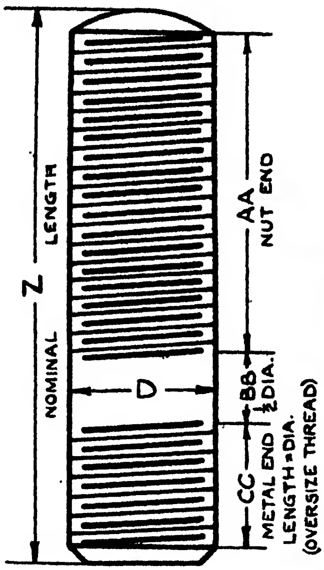
(*f*) **Tee Bolt** (fig. 75*f*). Very little used. Square and Tee heads are used in Tee slots of machine tables.

(*g*) **Eye Bolt** (fig. 75*h*). Used for providing a means of lifting and transport.

(*h*) **Hook Bolt** (fig. 75*g*). A typical application is shown.

Approximate proportions of types *b*, *c* and *d* are given in Table X, page 175.

Studs. Where space prevents the use of a bolt and nut, a stud having a thread at each end is used (fig. 76*a*). One end, known as the "metal end," having a thread of a length equal to the diameter of the stud, is screwed tightly into a tapped hole in the com-



B.S. STUD

FIG. 76a

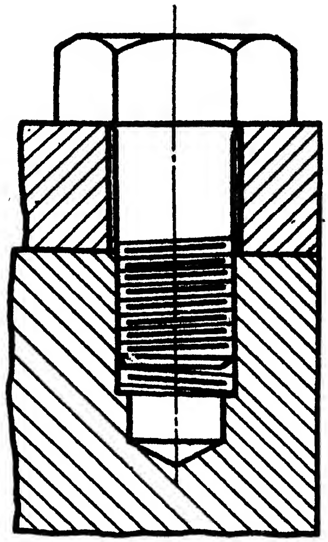
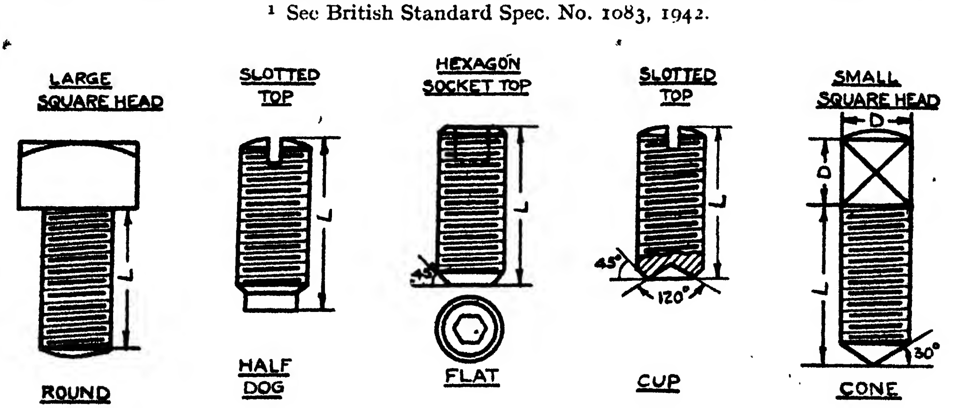


FIG. 76b

ponent. The unscrewed length is equal to half the diameter on a standard stud.[1] Owing to the difficulty of inserting a stud tightly into the tapped hole, a bolt is often used instead as in fig. 76*b*.

Grub Screws. These are screws which are used, not for clamping, but for locating a component by means of the thrust on their end. Collars and pulleys are located on shafts by such screws. Various heads, and plain headless types, are in common use, the types having a head being called set screws. The point is obviously important for such an application, and it is always formed to a shape as in fig. 77 and usually hardened.

[1] See British Standard Spec. No. 1083, 1942.



SET SCREWS AND GRUB SCREWS

FIG. 77

A flat end would soon burr over and prevent removal.

NUTS

Standard hexagon nuts are used very freely, but for special purposes there are a few other types, many of which are not standardised, but are designed to suit a particular job (fig. 78).

(*a*) **Flanged Nut.** Gives larger bearing surface. The usual practice is to use a separate washer with standard nut.

(*b*) **Domed Nut.** Used to improve appearance on such work as instrument panels.

(*c*) **Knurled Nut.** Used where finger tightness and quick removal desired. (Only used for small sizes such as on terminals for electrical apparatus.)

(*d*) **Wing Nut.** Used where continual easy removal desired, *e.g.*, on hinged lids of jigs or fixtures (B.S.I. standard proportions shown).

(*e*) **Slotted Ring Nut.** For use on large screws of small pitch where adjustment by a C spanner (see fig. 23*d*, page 14) is convenient, *e.g.*, on machine spindle.

(*f*) **Capstan Nut.** Has similar application to (*e*). Occasionally the holes are drilled in one of the flat faces instead of the curved surface.

Any component having an internal screwed hole may be a nut even though it is not used for clamping in the usual sense of a nut. The traverse nut for a lathe cross slide is an example of this (fig. 78*g*).

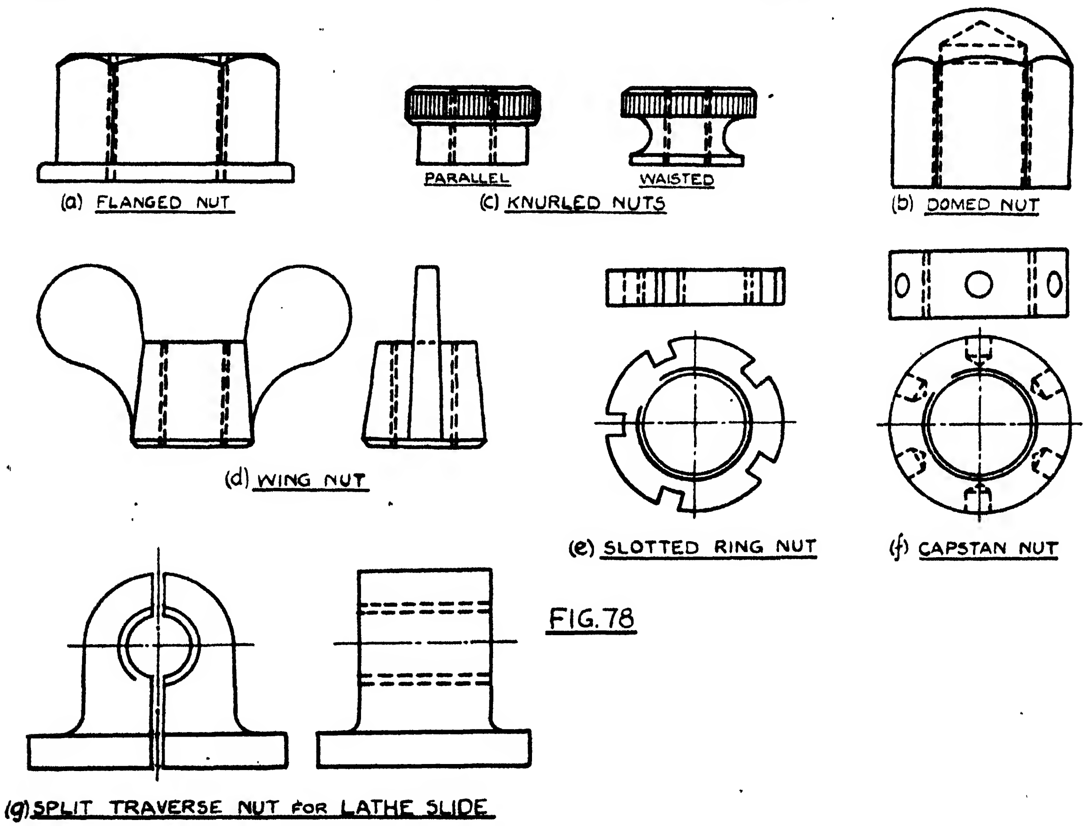
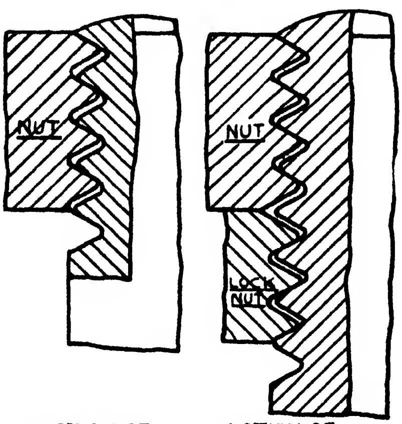


FIG. 78

NUT LOCKING

There is always a small working clearance between the threads of a nut and bolt, even in the highest class of work, and however the nut is tightened up there is a tendency for it to work loose under the vibration of a machine or instrument. To prevent this some means of locking the nut is necessary.

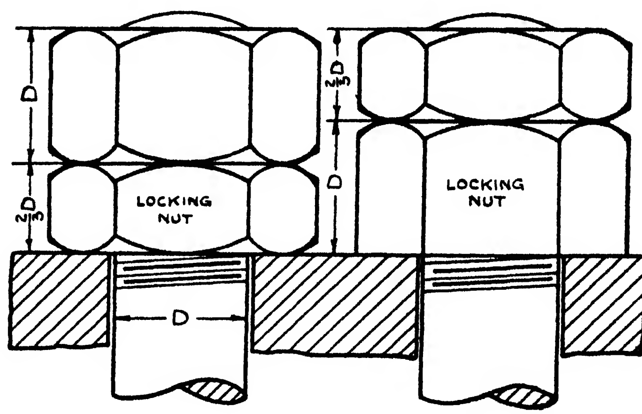
Locknuts. The most common method is to use an additional thinner nut, called a locknut. Exaggerating the clearance, the action of a single nut and the locking effect of the second nut, in thrusting the clearance of the two nuts on to opposite flanks, causing a wedging action on the flanks in contact, is shown in fig. 79*a*. Notice that the upper nut is supporting the load and should therefore, theoretically, be of full depth, whilst the lower nut is actually locking and may be thinner. In practice the full nut is first tightened on the work, then a locknut put on and, holding the upper nut with a spanner, the lower eased back very slightly to jamb the threads as shown. Because of the inconvenience of using a spanner on a thin nut put on first, which is the correct order, the thin lock nut is usually placed on top as shown. Locknuts have a chamfer on each side.



ACTION OF SINGLE NUT

ACTION OF TWO NUTS

FIGS 79a&b



CORRECT (THEORETICALLY)

INCORRECT (THEORETICALLY)

Taper and Split Pins. A positive method of securing a nut is to drill through the nut and bolt after tightening, and then insert a pin. Standard taper pins, used in reamed holes, remain in position by friction, whilst the split pin has its ends opened after insertion in the drilled hole. This method demands great care to ensure that the nut does not work loose whilst being drilled, as there is no possibility of tightening up after drilling (except by making an entirely new hole). It is used principally on larger work such as marine engine nuts.

To avoid the necessity of drilling the nut, slotted nuts are used providing the equivalent of three drilled holes (fig. 80*a*). Since the slots reduce the effective length of the thread, a more common type is the castle nut (fig. 80*b*) (Table VIII, page 174). A slight adjustment is possible with both of these nuts by tightening one-sixth of a turn to insert the pin. Disadvantages of the use of pins are the weakening effect of the drilled hole in the bolt and the lack of provision for tightening on wearing.

Spring Washers (Single, double. Fig. 81*a*). These are used frequently, their effect being to add a thrust on the bearing thread flanks. The double coil

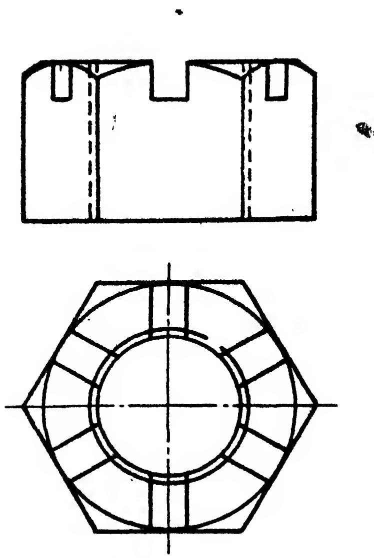


FIG. 80a—SLOTTED NUT

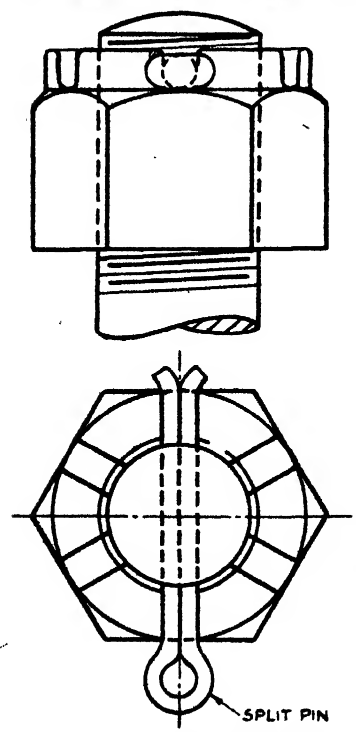
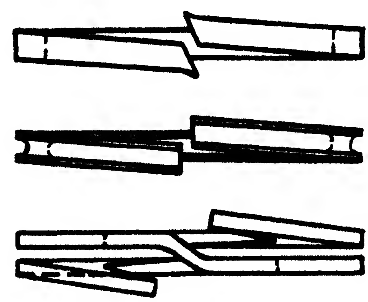


FIG. 80b—CASTLE NUT

type are often known as Thackray washers, and the single as Grover washers. Some types add to the locking effect by upturned ends, which on the nut loosening would dig into nut and work face. It is impossible to remove this type without damage to faces.

Locking Plates. Thin pierced copper or brass strip, of length to suit the job, forms an effective lock for smaller sizes of nut. The strip is put over the screw, and, after tightening the nut, one end is turned down over a convenient edge, whilst the other end is turned up round the nut (fig. 81*b*). An application showing two nuts locked by this method is given on page 139, fig. 177, and a heavier type



SPRING WASHERS

FIG. 81a

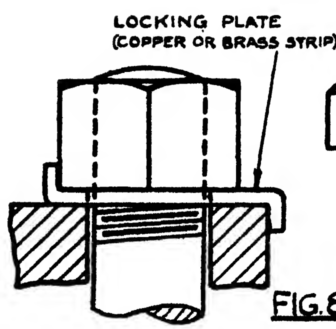


FIG. 81b

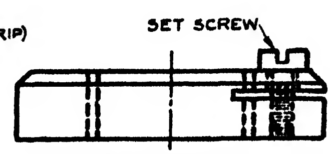
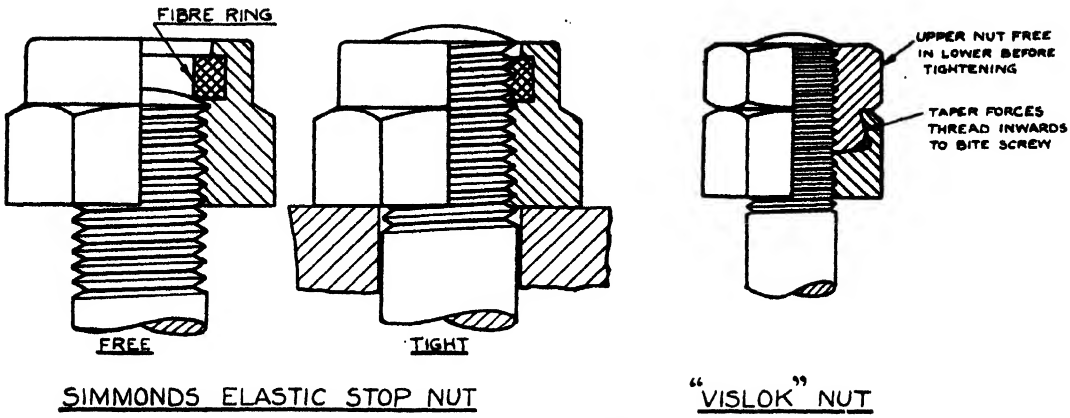


FIG. 81c—RING TYPE

is illustrated on the motor cycle crank shaft, page 141, fig. 179.

A special nut which is locked by a device frequently used on marine engines is shown on page 137, fig. 175. Ring type nuts are often locked by making a thin slit across, parallel to face, and inserting



FIGS 82

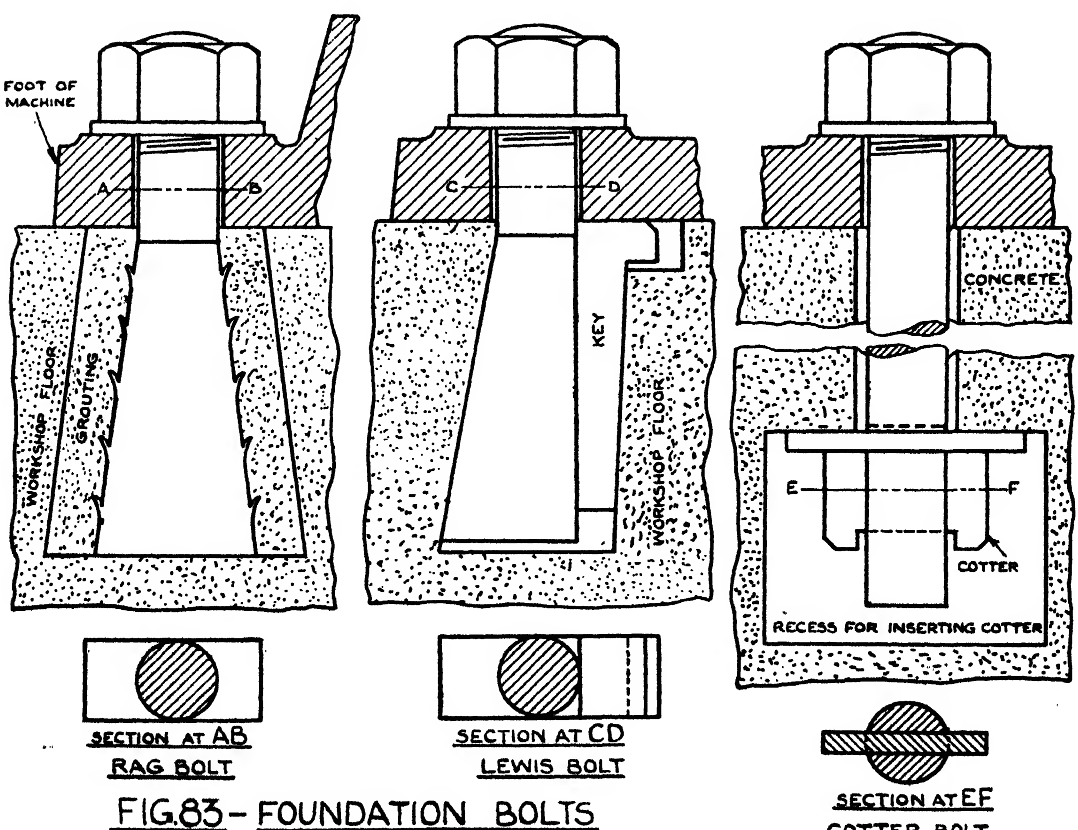


FIG.83 - FOUNDATION BOLTS

a grub screw to close the slit and pinch the thread (fig. 81*c*).

Locking Devices. There are also very many special patent devices which are quick to assemble and effective in action ; examples of some are shown in fig. 82.

Washers. Washers are made in standard sizes (approximately 2D in diameter and $\frac{3}{16}$D in thickness where D = bolt diameter), either in black or bright mild steel, and are used when it is necessary to prevent a nut wearing a surface in turning.

Foundation Bolts. For fixing machinery in position special foundation bolts are used. Fig. 83 shows three types of bolt for this purpose.

(*a*) **Rag Bolt.** Positions are marked either from a template or from the machine itself, and holes roughly bored out from the floor, sufficiently large to allow the bolt to be suspended freely in position whilst cement is poured round to fill up the space. When the cement sets the rough gashed edges on the taper prevents the bolt drawing out. Very heavy machinery, as well as comparatively light equipment, is satisfactorily secured by this method. The bolts are said to be "grouted in," and sometimes the grouting is made with molten lead instead of cement.

(*b*) **Lewis Bolts.** When there is a possibility of having to move a machine fixing bolt, the rag bolt is unsatisfactory as it can only be moved by breaking up the cement. A Lewis bolt can be used, set in the same way as a rag bolt, but on taking out the key, the bolt can be removed. It must always be noted that the key is of such a width that the wide end of the bolt can pass through the top of the hole.

(*c*) **Cotter Bolts.** The pull of the bolt on tightening the nut is taken by the cotter underneath the washer.

Bolts of Maximum Strength. A thread is weak where the stress is concentrated at the sudden change of section, that is, at the end of the screw thread, or at any sharp corners. To design a screw for maximum strength and minimum weight, the effective diameter or area of section should be constant throughout, so tending to achieve uniform stress distribution. Sharp corners must be avoided by using a radius. Examples are shown on pages 137, 145, figs. 175, 184, on marine engines. The diameter is enlarged at the middle to give a bearing surface. This type of bolt is often used on fast moving parts such as connecting rods, and in aircraft practice. An alternative device is to make the unscrewed portion hollow, so reducing its area.

EXERCISE IX

(1) Prepare an enlarged view 10 times full size of the profile of the following threads :

(*a*) B.S. Whitworth. (*d*) Square.
(*b*) Sellers. (*e*) Buttress.
(*c*) British Association. (*f*) Acme.

In each case make the pitch $\frac{1}{8}$ in. and draw three complete threads.

(2) (*a*) Draw three views of a 1 in. B.S. Whit. hexagonal nut.

(*b*) Draw three views of a $\frac{3}{4}$ in. B.S. Whit. hexagonal head bolt $2\frac{1}{2}$ in. long screwed 1 in. (10 T.P.I.).

(*c*) Draw three views of a $\frac{3}{4}$ in. B.S. Fine hexagonal head bolt $2\frac{1}{2}$ in. long screwed 1 in.

(3) (*a*) Draw three views of a 1 in. B.S. Whit. hexagonal slotted nut. (See page 174.)

(*b*) Draw three views of a $\frac{3}{4}$ in. B.S. Whit. hexagonal castle nut to dimensions given. (See page 174.)

(4) A stripper bolt has a $\frac{5}{8}$ in. B.S. Whit. thread $\frac{3}{4}$ in. long, shoulder $\frac{7}{8}$ in. diameter 3 in. long, and socket cap head, $1\frac{1}{16}$ in. diameter, $\frac{5}{8}$ in. high with hole for hexagon key, $\frac{5}{16}$ in. across flats, $\frac{1}{2}$ in. deep. Draw two views of the bolt.

(5) A spigoted cover is secured by three $\frac{1}{2}$ in. studs. Show a sectional view passing through one of the studs, showing cover with studs and lock nuts. Cover $6\frac{1}{2}$ in. diameter $\frac{3}{4}$ in. thick, spigot $3\frac{7}{8}$ in. diameter $\frac{1}{4}$ in. deep, pitch circle of studs 5 in. diameter.

(6) Show a sectional view and plan looking on nuts of a plate $\frac{5}{8}$ in. thick secured to a plate $\frac{1}{2}$ in. thick by two screws : (i) a $\frac{3}{8}$ in. cheese head screw in a counterbored hole in the $\frac{5}{8}$ in. plate with double coil spring washer (0·71 in. diameter. 0·096 in. closed thickness) ; (ii) a $\frac{3}{8}$ in. countersunk screw with washer and castle nut. Specify the necessary length of each screw.

(7) Fig. 84*a* shows the screw of a lifting jack, the screw being 1½ in. outside diameter 5 T.P.I. R.H. Draw an elevation of the screw without nut and washer, and a sectional elevation of a suitable nut 1¾ in. thick, 2¾ in. diameter.

(8) Draw a plan and half sectional elevation of two types of ring nut suitable for a spindle screwed 2⅝ in. diameter 12 T.P.I. Make the nuts ¾ in. thick.

(9) A traversing screw is 5½ in. long, 2 in. outside diameter, with a two start Acme thread of ⅝ in. lead (pitch 5/16 in.). L.H. The head is 2¾ in. diameter, ¾ in. high, with flats 2¼ in. across. Draw an elevation looking on the flats.

(10) An aircraft control wire is connected to a screwed turnbuckle; fig. 84*b* shows one of the connections. Show the complete turnbuckle assembly in section with centres of 5/16 in. holes, 7 in. apart.

(11) Fig. 84*c* shows a double screw which is turned through 120° by a lever fitting over the square shank. The ends are screwed R.H. and L.H. and in turning they move the segments of a friction clutch out or into engagement. The movement of each part is to be ¼ in. while lever turns 120°. The threads are three start square. Complete the drawing of the screw (see fig. 128*b*, page 101).

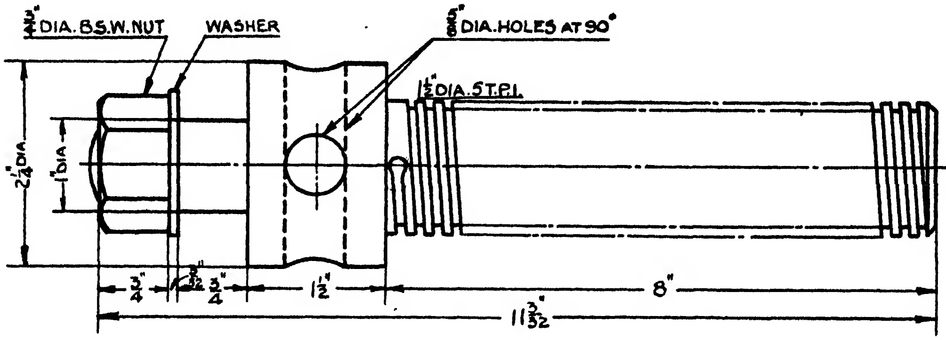


FIG. 84a JACK SCREW MATERIAL:- MILD STEEL

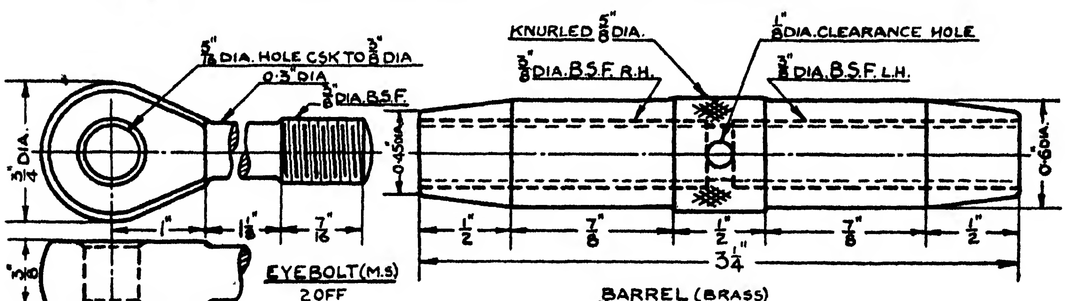


FIG. 84b – TURNBUCKLE

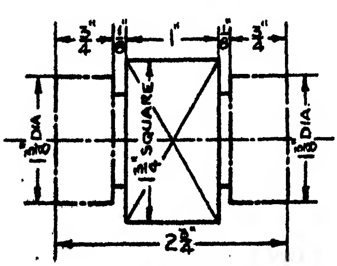


FIG. 84c

Chapter VI

THE WORKING DRAWING

WHEN an inventor conceives a mechanism he makes a drawing to illustrate the idea; this drawing is then passed to a designer, who carefully works out the various details of the mechanism in a practical way, so that each part can be manufactured and that all the parts fit and work smoothly together. From this assembly drawing, each detail can be carefully picked out and separate working drawings made to guide the production of each detail. Copies of these working drawings are then sent to all the workshops and offices concerned. The working drawing, therefore, is for the following purposes:

- (i) To show the shape of every detail and where it is machined.
- (ii) To give all necessary dimensions.
- (iii) To give particulars of material, manufacturing notes, any heat treatment necessary, and any protective finish required.

Detail drawings are usually made showing the component either (i) *in the position it occupies on the job*, or (ii) *in the position it assumes during the main machining operation*. Suppose, for example, a working drawing of the base block (fig. 85*d*) is to be drawn from an arrangement drawing of the machine. To show every particular clearly, three views are necessary, having a total width of 12¾ in. and total height of 11¼ in. These views will fit conveniently into a standard sheet of about 22 in. by 15 in., allowing ample space round the views for dimensions. The first step is to mark out very lightly the space occupied by each view, leaving a symmetrical margin and space between each view. Within these areas draw in the centre lines, including those for all the holes (fig. 85*a*). Notice that it is not usually good practice to finish off any one view, but to do all the views concurrently projecting from one to the other. This not only saves time in setting compasses, etc., but also promotes accuracy.

For the next step, draw all the circular parts and more important arcs and lightly fill in the main drawing in each view (fig. 85*b*). Check this over and then line in boldly with clear firm lines. Add the necessary section lines and machining marks and then insert blank dimension lines and limit lines. Check that every necessary dimension is allowed (fig. 85*c*).

Finally, add dimensions and instructional notes and titles (fig. 85*d*). Notice that the machining marks are put on before dimensioning to ensure that the dimensions necessary for the machining are given.

Before considering the dimensioning of a drawing it is interesting to note the various types of drawing used in practice.

1. **The General Arrangement.** All details shown fitting in position, each detail being referenced and scheduled (see fig. 87, page 70).

1a. The general arrangement may only show the position of every detail, probably not sufficient information being given to detail each part. A drawing, often called a layout, will supply all the necessary information for complete detailing. To do this the layout shows several views of the complete assembly and often additional part views.

2. **The Sub-Assembly.** A smaller general arrangement. These are made not only to group together parts of a machine such as a headstock, but also for much smaller assemblies where two or more details are secured together as a unit, such as, for example, a contact spring and contact. This practice is often helpful in the efficient storage of

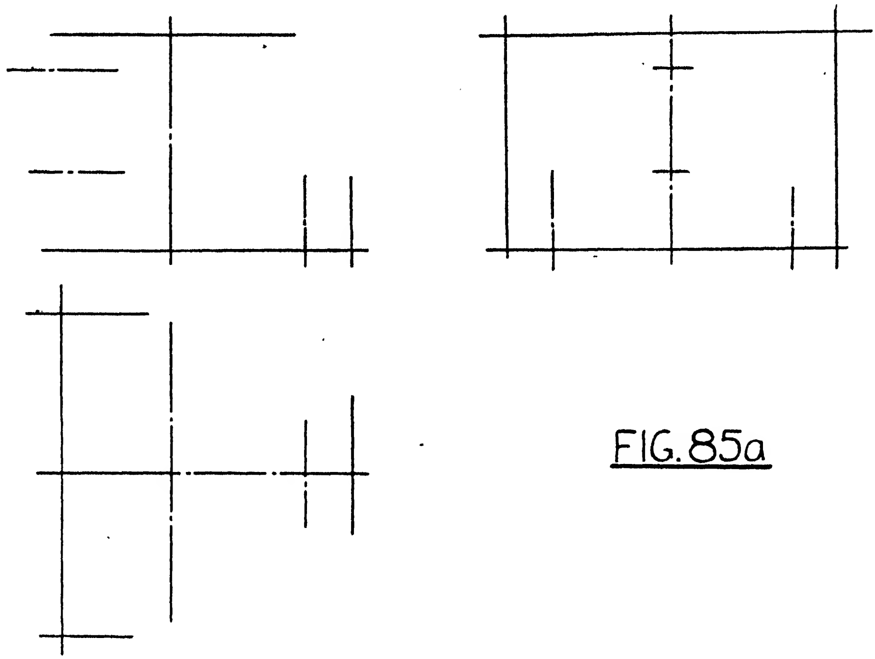


FIG. 85a

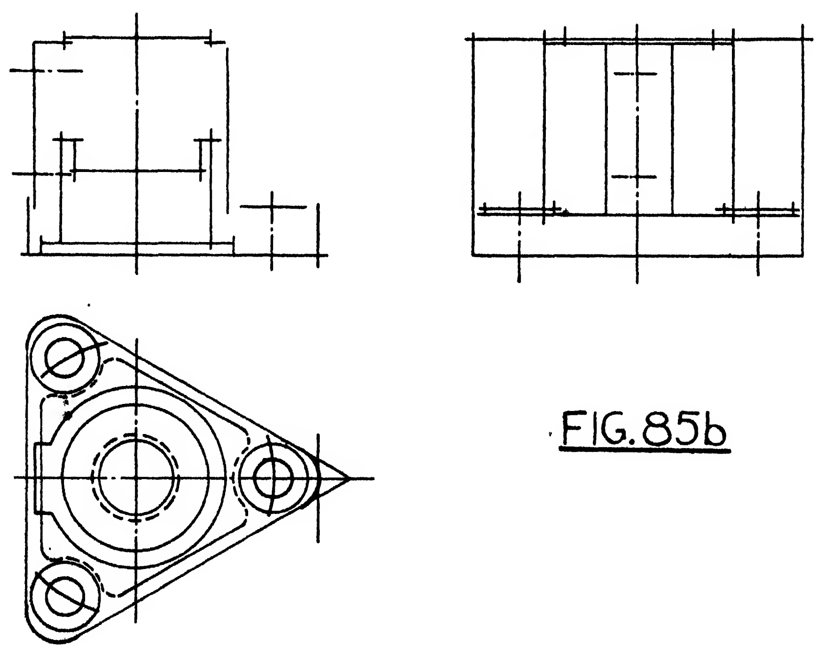


FIG. 85b

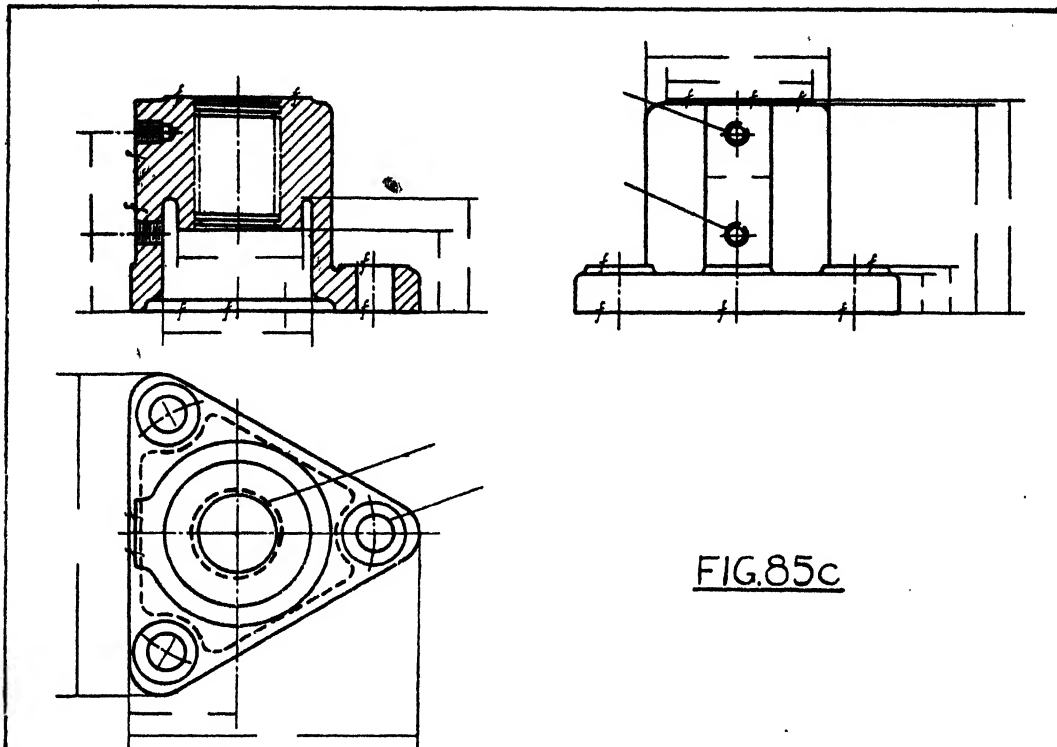


FIG. 85c

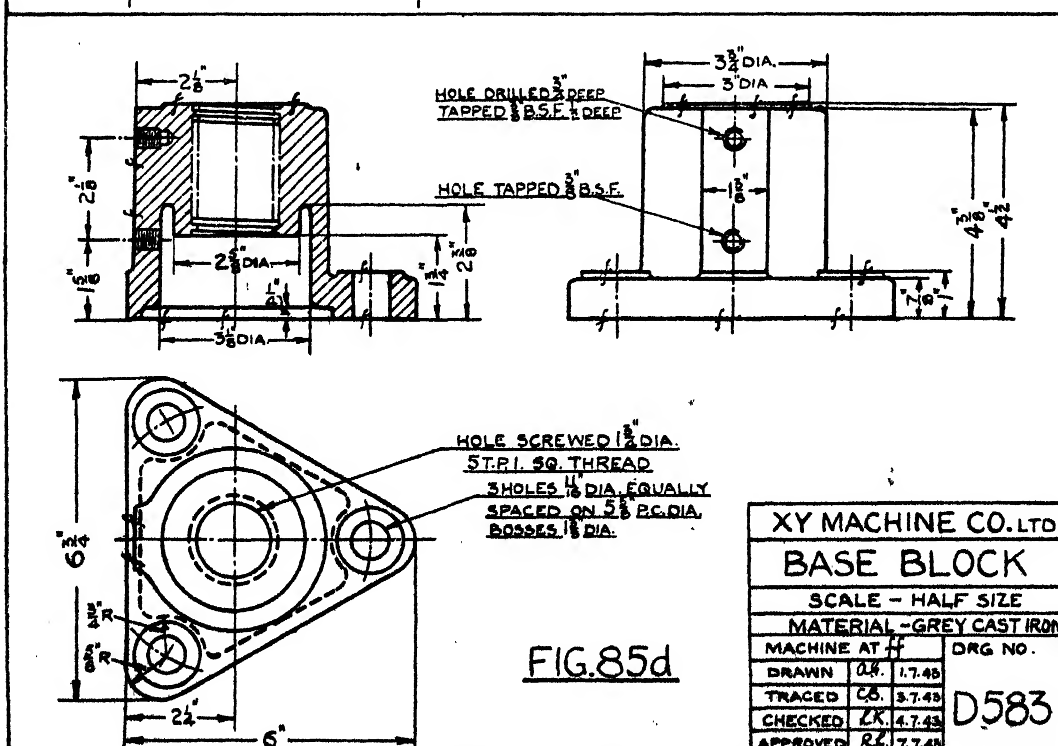


FIG. 85d

parts in process of assembly or manufacture.

3. **The Detail Drawing.** A fully dimensioned drawing to guide the production of one complete detail.
4. **A Casting Drawing.** This gives particulars and dimensions for the pattern maker only. When such a drawing is used, a separate drawing giving particulars of machining operations on the same detail is necessary.
5. **Operation Drawing.** A separate drawing issued for each machining operation on a particular detail. Only the dimensions for the particular operation are shown. This type of drawing is only used for production of very large quantities.
6. **Tool Drawing.** A jig or tool drawing is only used on one or two occasions, and therefore it is common practice to dimension several details on the actual general arrangement, instead of drawing each detail separately.

Examples of type 2 are given (figs. 86, 87). Other types are seen throughout the book.

DIMENSIONING OF DRAWINGS

It must be remembered that the dimensions on a drawing are of prime importance. In engineering practice a print of a drawing is **never scaled**; every necessary dimension must be given and must be accurate. Accuracy in the actual drawing is essential as a check on the design, accuracy in dimensioning is even more important. A component drawn out of scale, but with accurate dimensions given could be made correctly.

Whilst certain practices vary in different drawing offices in spite of the recommendations of the committee of the British Standards Institution, certain fundamental principles are invariable. The drawings in this book have been dimensioned in accordance with the recommended practice of the B.S.I.

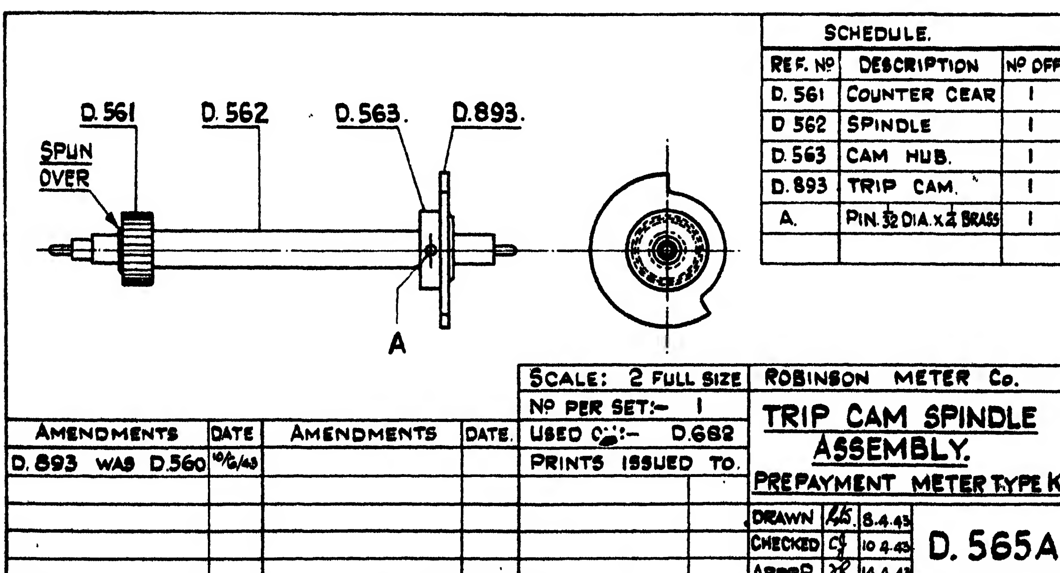


FIG. 86

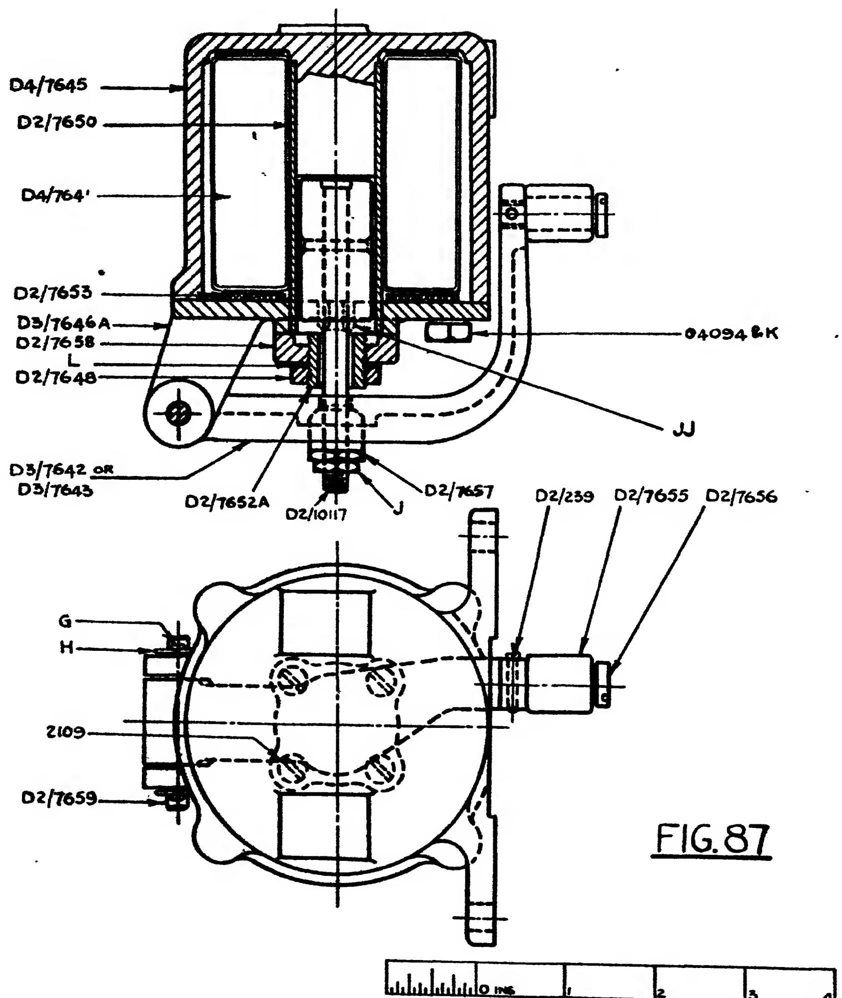


FIG. 87

SCHEDULE		
REF.	DESCRIPTION	Nº OFF
D2/239	SPLIT PIN	1
D4/7641	ASSEMBLY OF COIL	1
D3/7642	CONTROL COIL LEVER L.H.	1
D3/7643	" " R.H.	1
D2/10117	ASSEMBLY OF MOVING CORE	1
D2/7650	COIL TUBE	1
D2/7652A	GAP ADJUSTING SCREW	1
D2/7653	PACKING WASHER	2
D2/7655	ROLLER	1
D2/7656	ROLLER PIN	1
D2/7657	ADJUSTING NUT	1
D2/7658	END CAP	1
D2/7659	FULCRUM PIN	1
D2/7648	NUT	1
D4/7645	COIL HOUSING	1
D3/7646A	YOKE	1
04094	¼" WHIT. x ⅝" L. HEX HD. SCREW M.S.	4
2109	2 B.A. x ⅜" L. CSK HD SCREW BRASS	4
G	SPLIT PIN 1/16" DIA. x ½" L. M.S.	2
H	WASHER ½" 9/32 DIA x ¼ CL x 1/32 TH. M.S.	2
J	¼ WHIT STD HEX. LOCKNUT M.S.	1
K	WASHER ¼ DIA. GROVER PH. BR	4
L	SHAKEPROOF WASHER (INT) 5/16" DIA.	1
JJ	BUSH STD CRYSTALLATE Nº 8186	2

MATERIAL

FINISH
STEEL PARTS - ZINC PLATE
BRASS " - M.N.P

TITLE
ASSEMBLY OF CONTROL COIL

SCALE - HALF SIZE

DRAWN	J.K.	22.2.43	ELECTRIC SIGNAL COMPANY LTD LONDON
TRACED	[illegible]	27.2.43	
CHECKED	K.L.J.	3.3.43	DWG Nº D4/7660
APPROVED	[illegible]	17.3.43	

(Fig. 87 by permission of Messrs. The Siemens & General Electric Railway Signal Co. Ltd.)

where this is definitely stated, and otherwise, in accordance with common office practice.

Each part of a component, boss, rib, hole, etc., needs dimensions—(i) *to give its size*, (ii) *to give its position*. The following general rules will serve as a guide in the dimensioning of any drawing :

PRINCIPLES

1. Every necessary dimension must be given, and given once only. Insert the dimension lines completely. Then check over to see that every size is covered. To determine if any dimensions have been omitted, go through all the manufacturing operations mentally to see if the job can be made from the data given. Then insert the figures carefully.
2. Dimensions should be given in accordance with the manufacturing process, that is, to suit the pattern maker's methods, or tool room practice (see fig. 163, page 128), or the general machine shop.
3. Place the dimension on the view in which you would naturally look for it if using the drawing. Remember that some views give a more obvious impression of a certain part of an object than the other views. Choose these obvious positions.

CURRENT PRACTICE (see fig. 88)

1. Dimensions should be spaced clearly, mainly off the drawing, not crowded closely round the views.
2. Limit lines should be thin continuous lines running almost up to surface concerned, with only a small break, to a point about $\frac{1}{16}$ in. beyond the given dimension line.[1]
3. Limit lines may cross other limit lines, for example, those at right angles to them, but should not cross a dimension line. This can be arranged by inserting the smaller dimensions nearer to the object and the larger further away.
4. Dimension lines should terminate with neat arrowheads (approximately $\frac{1}{8}$ in. long) at each end. The arrow head must precisely touch the bounding limit lines or surfaces. A dimension line for a radius has an arrow head at one end only, that away from the centre.
5. Figures should be inserted in a break midway along the dimension lines.
6. Figures should be inserted in the break, parallel to the dimension line in every case. This means, of course, that horizontal dimension lines only have figures reading from the bottom of the sheet. Vertical dimension lines should have figures reading from the right-hand side only. (This recommended practice is not followed in every office.)
7. Dimension in a narrow space such as $\frac{1}{8}$ in., etc., may be inserted in the space between two reversed arrow heads.
8. Every dimension required should be available without a long calculation from several other dimensions.
9. Duplication of dimensions should be avoided. It tends to error if an alteration is made to the component at any time, for one of the dimensions duplicated is liable to remain unaltered. An allowable duplication is the giving of an overall dimension on a long job having several intermediate dimensions.[2]
10. The distinguishing abbreviations DIA. or DIAM. and RAD. or R. should always be given where they apply.
11. Instructional notes such as those referring to the drilling or tapping of holes should be printed near the part concerned, and a pointer line drawn from the note to the actual

[1] The drawings throughout this book were prepared before the issue of the new specification, and in this respect only do not conform to the new requirement.

[2] See B.S. Spec. No. 308, 1943, page 25.

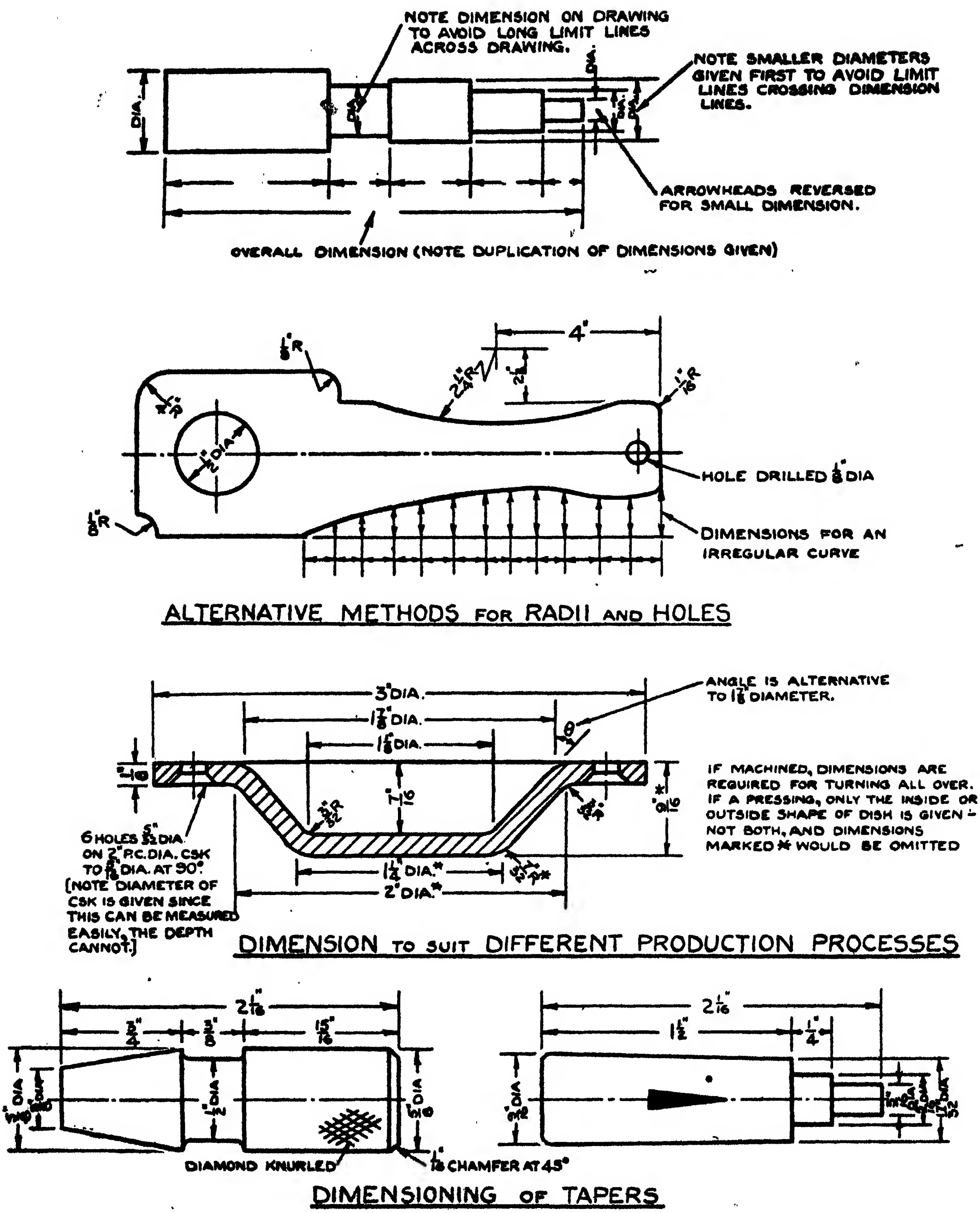

NOTE DIMENSION ON DRAWING TO AVOID LONG LIMIT LINES ACROSS DRAWING.
NOTE SMALLER DIAMETERS GIVEN FIRST TO AVOID LIMIT LINES CROSSING DIMENSION LINES.
DIA.
ARROWHEADS REVERSED FOR SMALL DIMENSION.
OVERALL DIMENSION (NOTE DUPLICATION OF DIMENSIONS GIVEN)
4"
HOLE DRILLED 1/8" DIA
DIMENSIONS FOR AN IRREGULAR CURVE
ALTERNATIVE METHODS FOR RADII AND HOLES
3" DIA.
1 7/8" DIA.
1 5/8" DIA.
ANGLE IS ALTERNATIVE TO 1 7/8" DIAMETER.
IF MACHINED, DIMENSIONS ARE REQUIRED FOR TURNING ALL OVER. IF A PRESSING, ONLY THE INSIDE OR OUTSIDE SHAPE OF DISH IS GIVEN - NOT BOTH, AND DIMENSIONS MARKED * WOULD BE OMITTED
6 HOLES 5/32" DIA. ON 2" P.C. DIA. CSK TO 5/16" DIA. AT 90°. [NOTE DIAMETER OF CSK IS GIVEN SINCE THIS CAN BE MEASURED EASILY, THE DEPTH CANNOT.]
1 1/4" DIA.*
2" DIA.*
DIMENSION TO SUIT DIFFERENT PRODUCTION PROCESSES
2 1/16"
3/4"
3/8"
15/16"
1 1/2"
1/4"
DIAMOND KNURLED
1/16" CHAMFER AT 45°
DIMENSIONING OF TAPERS

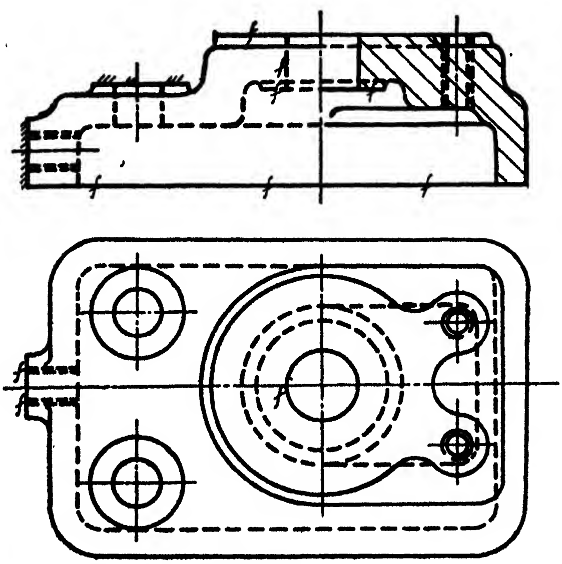
FIG. 88

spot. Pointer lines are thin continuous lines having one arrow only, at the actual place of application.

12. Radii and curves are dimensioned in various ways according to their size. These methods, and dimensioning of tapers, etc., are illustrated in fig. 88.

INSTRUCTIONAL NOTES, ETC.

The working drawing in practice must give much more information than is usually given on a drawing in class.



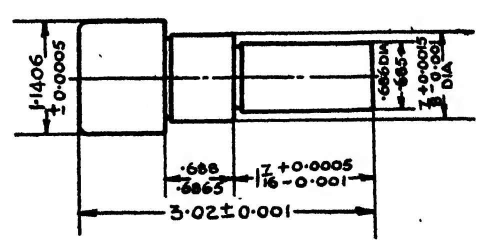
ALTERNATIVE METHODS OF SHOWING MACHINING

FIG. 89.

The draughtsman must have an understanding of the function, and of the method of making and of assembling the part which he is drawing, since these points will control the instructional notes and the specification of the required limits of accuracy.

Machined faces of a casting or forging are indicated on a working drawing by methods such as the following: (i) by letters *ff* along the face; (ii) by short inclined lines along the face[1]; (iii) by red ink lines on the print, along the face (fig. 89). Of these, probably the first is the best; the method (ii) is also used to indicate welding and the method (iii) is liable to an omission of the red ink on one or more of a batch of prints.

Limits. A study of the methods of specifying the accuracy required is outside the scope of this text-book, but briefly it should be noted that great accuracy is required for easy assembly and interchange, whilst more generous allowances favour easy economical production. The draughtsman must consider *both* these factors. Suppose a shaft 1 in. diameter is to fit into a hole. It may need to fit loosely, or to be just free to turn, or to enter only with great pressure. Any such fit, running fit, push fit, drive fit or force fit may be assured by controlling the allowed variations from the nominal 1 in. diameter of shaft and hole. To do this an instruction is given that this particular hole on the job must not vary by more than, say, half a thousandth nor exceed a given size, while the largest allowable shaft size and permitted variation is also given. Fig. 90 shows some of the methods in common use. The method of showing the two extreme limits within which the job is acceptable has the advantage of giving the measurements directly; the maximum size on



ALTERNATIVE METHODS OF GIVING LIMITS

FIG. 90

[1] See Chapter X, page 115.

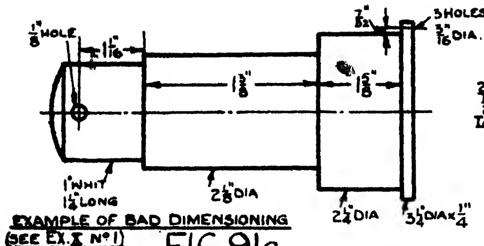


FIG. 91a

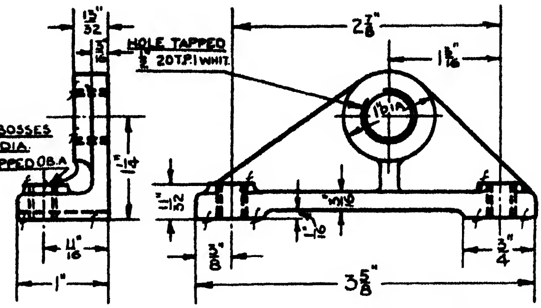
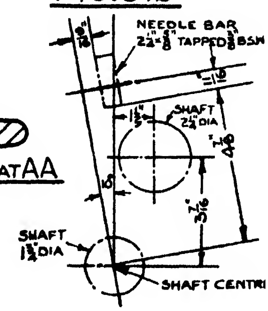


FIG. 91b



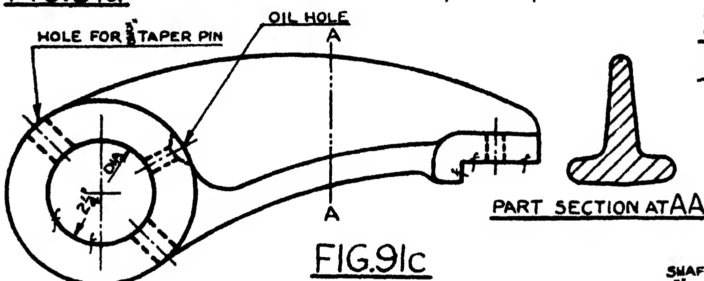


FIG. 91c

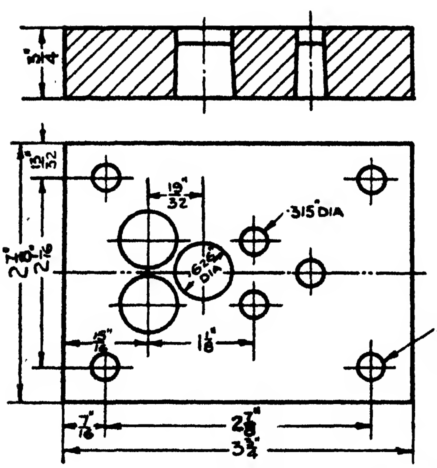


FIG. 91d

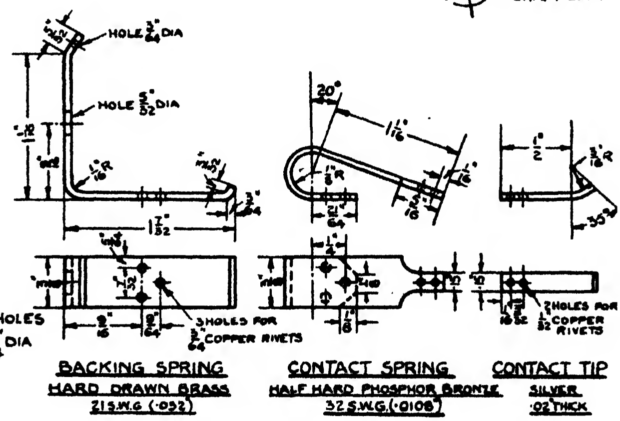


FIG. 91e

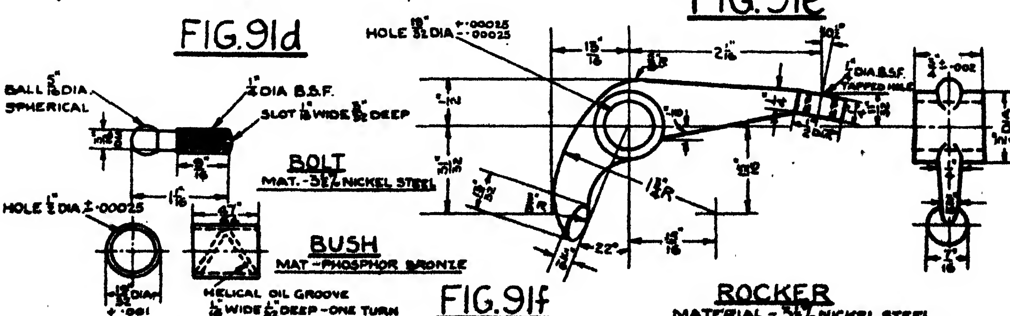
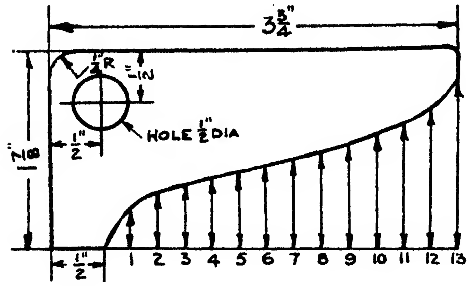


FIG. 91f

the $\frac{7}{8}$ in. diameter requires a small calculation to determine that it is 0·8765 in.

The accumulation of limits on a long job is an important matter; it is sometimes necessary to give a controlling overall limit. Absurd limits should be avoided, such as the specifying of a tolerance of 0·0001 in. on a component produced in a rough fitting shop or on a forging; consider the method of production on each drawing.



ORD	INCH	ORD	INCH
1	·37	8	·89
2	·51	9	·96
3	·59	10	1·05
4	·66	11	1·16
5	·71	12	1·28
6	·77	13	1·56
7	·83		

FIG. 92a

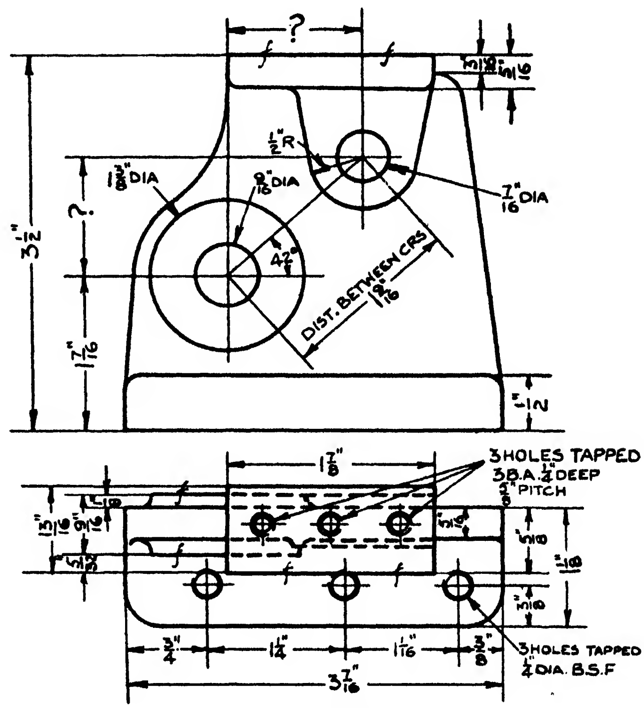


FIG. 92b

EXERCISE X

(1) Make a complete working drawing with dimensions of the spindle (fig. 91*a*), giving an elevation and end elevation looking on to the screw. Correct the bad dimensioning.

(2) Fig. 91*b* shows a gunmetal bracket. (i) Prepare a drawing suitable for the pattern maker only, allowing $\frac{1}{16}$ in. extra metal on all machined surfaces. (ii) Make a fully dimensioned machining drawing.[1]

(3) The lever shown in fig. 91*c* is to be modified to fit a $1\frac{3}{8}$ in. diameter shaft and to carry the needle bar shown. Prepare a complete working drawing, making the boss $2\frac{1}{2}$ in. long and needle bar end $2\frac{1}{4}$ in. wide. In position indicated, lever must clear the $2\frac{1}{4}$ in. diameter spindle.

(4) Make a fully dimensioned detail drawing of the die (fig. 91*d*). (See page 118.)

(5) The details of a contact spring assembly are given in fig. 91*e*. Prepare a sub-assembly with schedule.[1]

(6) Make an assembly drawing of the rocker arm showing a plan and elevation. Give a schedule of the details (fig. 91*f*).[1]

(7) Show all the necessary views for a working drawing of a wall box (fig. 108*f*, page 88). A $15\frac{1}{2}$ in., B $4\frac{3}{4}$ in., C 18 in., H 6 in., V $2\frac{1}{4}$ in., for a $2\frac{1}{4}$ in. shaft with ball bearing. Scale half full size.

(8) A wall bracket similar to that shown in fig. 108*d*, page 88, is to be made to the following dimensions: A 18 in., B $16\frac{3}{4}$ in., C $1\frac{1}{4}$ in., D $21\frac{1}{8}$ in., E $4\frac{5}{8}$ in., G $1\frac{1}{4}$ in., S $\frac{7}{8}$ in. Scale half full size.

(9) A gauge for a form tool is to be made from $\frac{1}{32}$ in. plate to the curve shown in fig. 92*a*. Make a dimensioned drawing twice full size.

(10) The bracket, fig. 92*b*, is to have a tolerance of 0·002 in. on the centre distances, and dimension from base to the smaller hole within limits of $\pm$ 0·0015 in. A variation of half a thousandth above and one thousandth below the nominal size is permitted for the holes. Show the upper and lower limit on these dimensions on a fully dimensioned working drawing.

[1] One dimension is omitted from figs. 91*b*, 91*e*, and 91*f*. Check to find it, and use a suitable dimension.

Chapter VII

PIPES AND PIPE JOINTS

VARIOUS pipes and joints are used in engineering practice, for conveying steam, water, air, gas and many other fluids. The kind of pipe used in any particular instance will be decided by consideration of the fluid conveyed, its corrosive action and temperature, the working pressure, the external conditions of the pipe line, etc. Piping is made in a wide range of sizes, by various methods, from steel, cast iron, wrought iron, copper or lead. In addition, there are many uses for

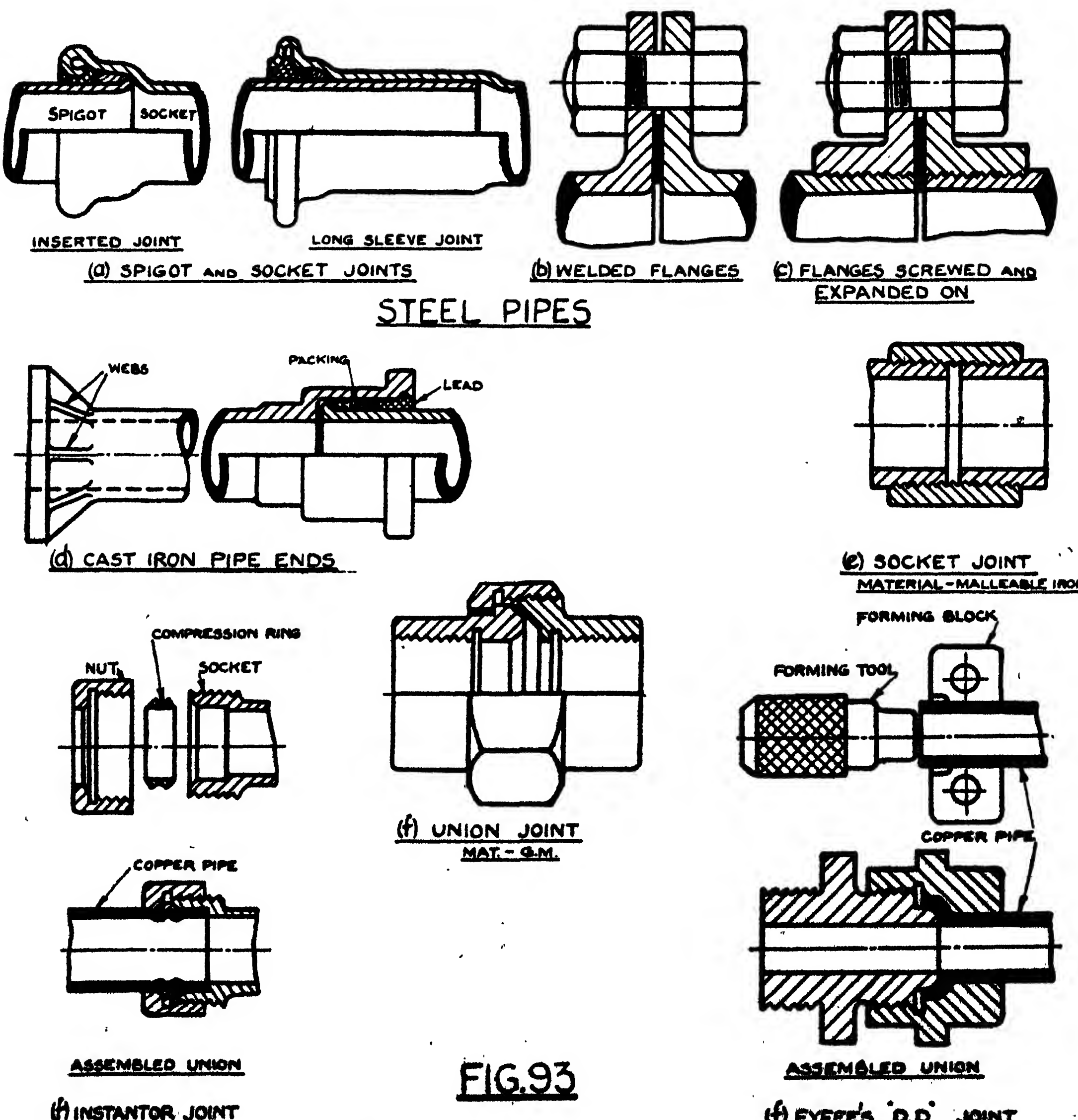


FIG. 93

(" *Instantor* " *and* " *D.D.*" *joint by permission of Messrs. Fyffe & Co. Ltd.*)

flexible armoured hose, with couplings to metal nozzles and valves. Large pipes for water, sewage, etc., are also made of earthenware or asbestos cement. All these pipes are jointed, curved and connected to mains by differing methods. When a pipe size is stated, the size given is that of the bore.

Steel Pipes. These are used for water, gas, sewage and air as well as for high-pressure steam, pipes for pressures up to 1,400 lb. per sq. in. being standardised. They have the following advantages over other pipes: greater strength, less liable to damage or breakage, can be made in longer lengths, give choice of jointing methods. There are two classes of steel tube, welded and weldless. The former are made by rolling steel plates into a cylindrical shape and then welding the joint. Weldless tubes are made by piercing an ingot whilst red hot, and after putting it on a mandrel, rolling it or drawing it through dies to form the size.

Steel pipes may be joined by a spigot and socket joints as in fig. 93*a* for sizes from 2 in. to 6 ft. diameter, for water, sewage, gas or air mains, but for gas and air the joints nowadays are usually welded. Flange joints are used for steam or where the pressure exceeds 300–350 lb. per sq. in. The flanges may be welded or screwed on the tubes as in figs. 93*b-c*.

Cast Iron Pipes. These are used also for water, gas, sewage, and steam, in sizes from $2\frac{1}{2}$ in. to 4 ft. diameter. The pipes are either flanged or made with spigot and socket ends, the ends in either case being cast solid with the pipe. Iron pipes are often cast by a process in which the molten iron is whirled round in a mould whilst solidifying, to give a good uniform structure. Such pipes are known as "spun pipes." Fig. 93*d* shows a C.I. pipe with flanged and with spigot and socket end joint.

Wrought Iron or Malleable Iron Pipes. These are used for water and gas at low pressure such as for domestic supply. The pipe is made by a welding process similar to that for steel tube. Lengths are connected by screwed couplings of the type shown in fig. 93*e*. Usual sizes are from $\frac{1}{4}$ in. to 6 in. diameter.

Copper and Brass Tubing. This is used extensively for hot water systems and on engine work. It is convenient in installation, since, with care, suitable bends may be made, and it has a pleasing appearance. It is often used also on account of its good heat-conducting quality.

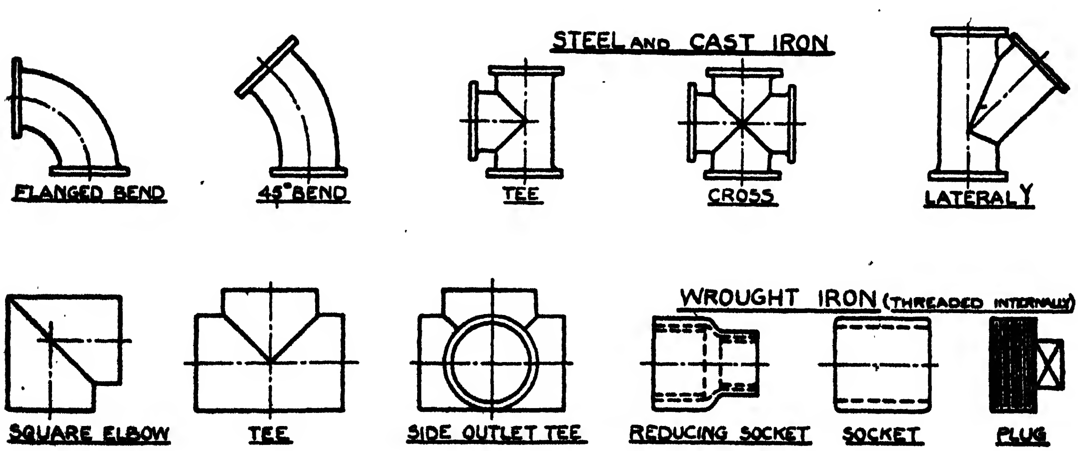


FIG. 94 – STANDARD PIPE FITTINGS

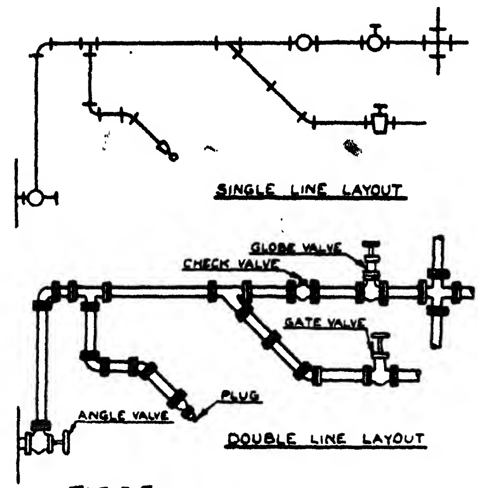


FIG.95 – PIPE LAYOUTS

Connections are made by soldering and by screwed nuts, or unions. There are also certain patent connections (fig. 93*f*).

Lead Pipe. This is produced by "squirting" or extruding molten lead through a die over a mandrel, and is used for domestic gas and water supply. With care lengths can be bent to shape very readily, and joints made by a soldering process. Such a connection is known as a wiped joint.

There are, of course, very many other applications of tubing, such as for electric wiring conduit, tubular construction, etc., but these are not within the scope of this chapter.

Pipe Fittings. In every pipe line there are various bends, branches, connections to other lines or apparatus. Lead and copper pipe are easily bent on site, but for the other pipes special standard fittings are made. Fig. 94 shows typical fittings for iron, steel and wrought iron pipes.

Pipe Layouts. When making drawings of a pipe run, the principal requirement is to specify the pipe size and the position of standard fittings; usually, a conventional single or double line layout is used, as shown in fig. 95. When it is possible to use a large scale, or for an unorthodox arrangement, the double line arrangement is to be preferred.

Pipe Supports. Whatever the material of a pipe run, provision must be made for supporting the pipe, except for underground work. The support must be sufficiently rigid to sustain the

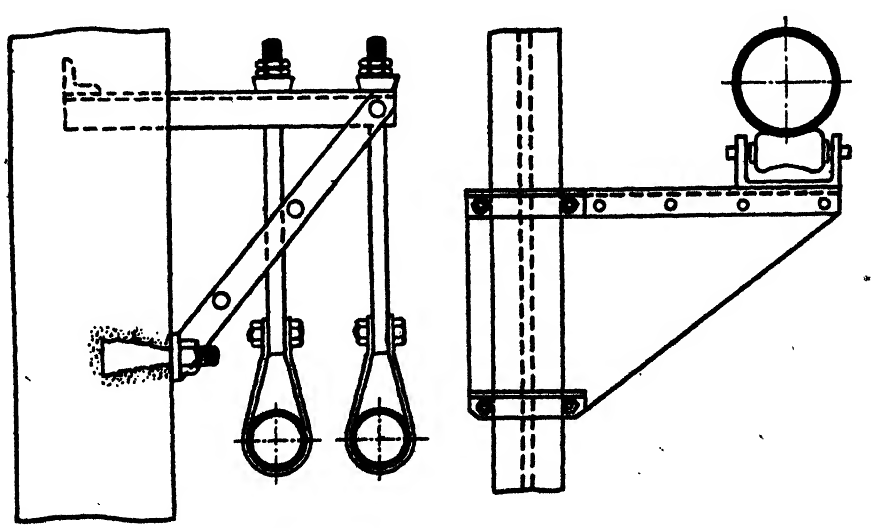


FIG.96 – PIPE SUPPORTS

weight of the pipe without allowing undue bending, and yet it must hold the pipe freely to allow it to elongate on expansion. This is especially important on long steam mains, where an arrangement of rollers, or flexible hangers as shown in fig. 96, are generally employed.

To allow for expansion in the actual pipe, between its fixed ends, expansion bends or loops as in fig. 97*a* are usually sufficient. An alternative arrangement is to provide an expansion joint (fig. 97*b*). These need careful erection and maintenance, as misalignment or sticking through faulty packing may easily cause a serious accident.

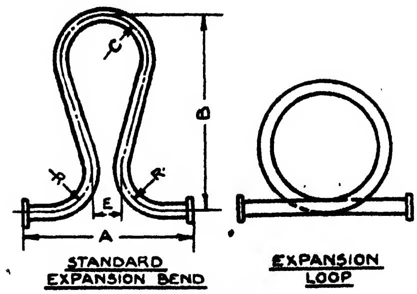


FIG. 97a

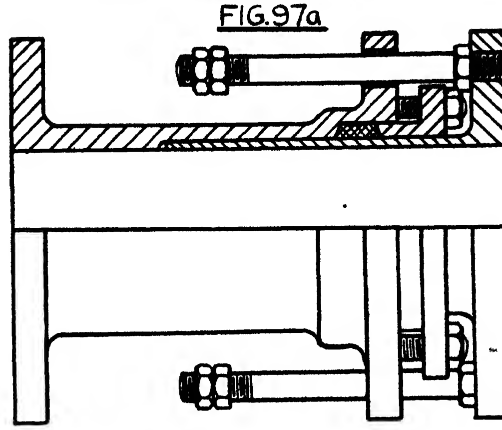


FIG. 97b – EXPANSION JOINT

Drainage of Pipes. Further precautions must be taken in a steam pipe line to prevent water condensing and accumulating. To avoid this dangerous condition, drain pockets are fitted at intervals, and if necessary, steam traps or steam separators which extract water from the steam by suddenly altering its direction and velocity (fig. 98).

Non-rigid Joints. For pipe runs which may be subjected to distortion due to subsidence or heavy traffic, joints having a little flexibility whilst keeping a perfect seal are needed. There are one or two patented types of joints suitable, such as the Victaulic joint and the Johnson coupling. The former couples the pipe positively, and seals by means of a moulded flexible ring; it allows a slight longitudinal movement as well as a little angular displacement. The Johnson coupling does not couple the

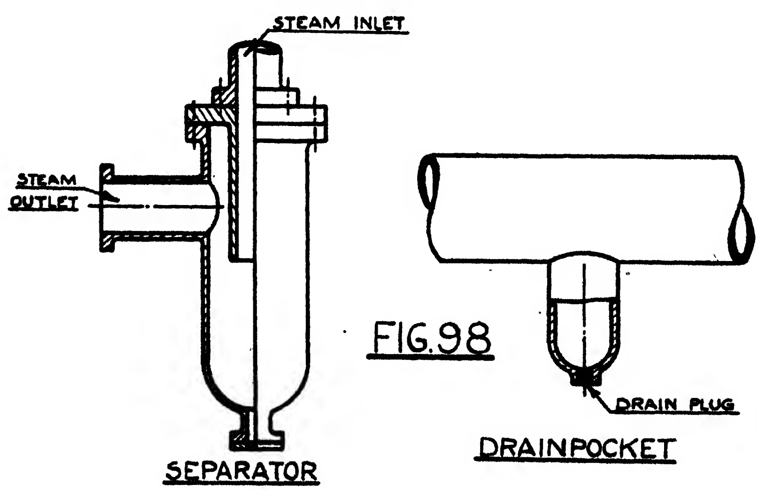


FIG. 98

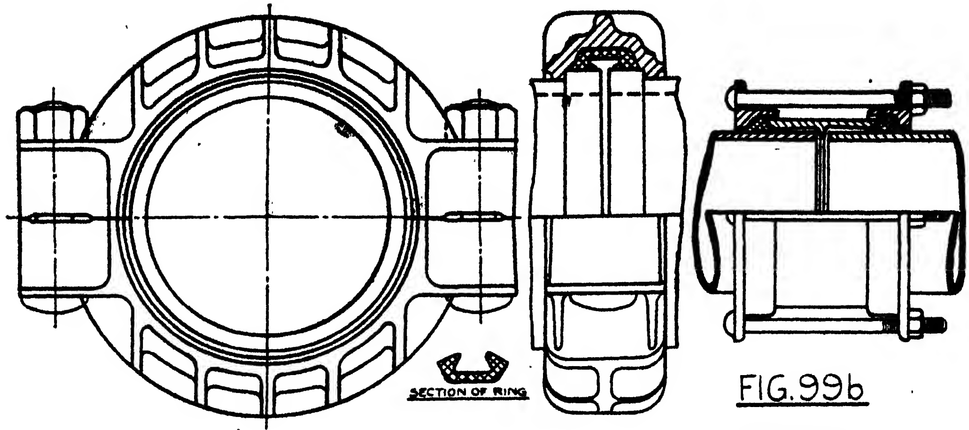


FIG.99b

JOHNSON COUPLING

FIG99a – VICTAULIC PIPE JOINT

(*Fig.* 99 *by permission of Messrs. The Victaulic Co. Ltd.*)

pipes positively, but gives a considerable angular flexibility (fig. 99).

PACKING AND JOINTING

Where metal surfaces meet, such as at pipe flanges or where rods emerge from vessels, a fit sufficiently perfect to prevent the escape of fluid is impossible, even with the highest class of machining, but a good joint may be effected by the use of packing. The packing will depend upon the nature of the fluid, its temperature and pressure, and shape of mating surfaces. For flanges, packing may be obtained in the form of sheet or specially moulded to suit the flange.

The simplest device for preventing leakage where a rod emerges from a vessel is to pack the rod with a shaped leather ring. This ingenious device, the U ring and hat ring as shown in fig. 100, was first used by Joseph Bramah, a pioneer in hydraulic power. Easy movement of the rod, without leakage of the fluid, is obtained by using a stuffing box in which a gland compresses the packing round the moving rod, as shown in

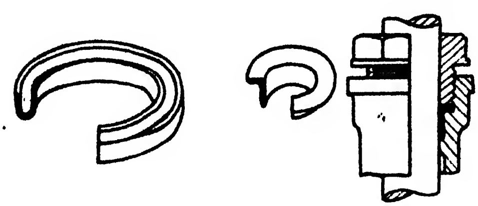


FIG.100

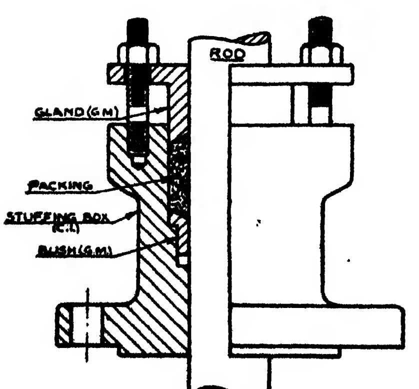


FIG.101–STUFFING BOX & GLAND

FIG. 102

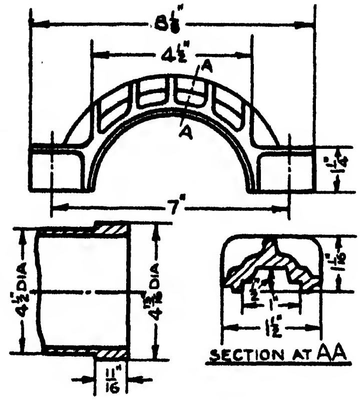


FIG. 103a

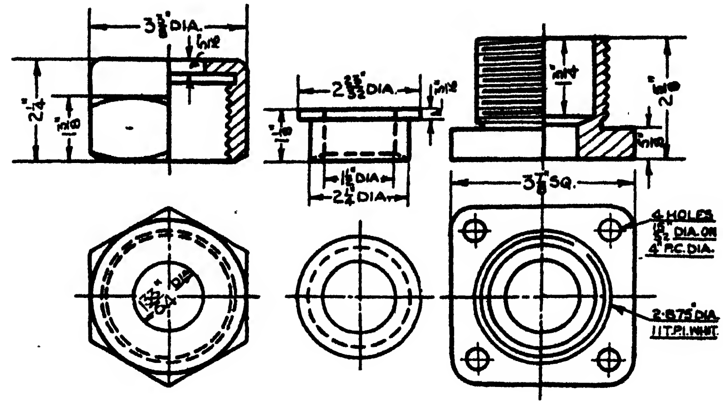


FIG. 103b

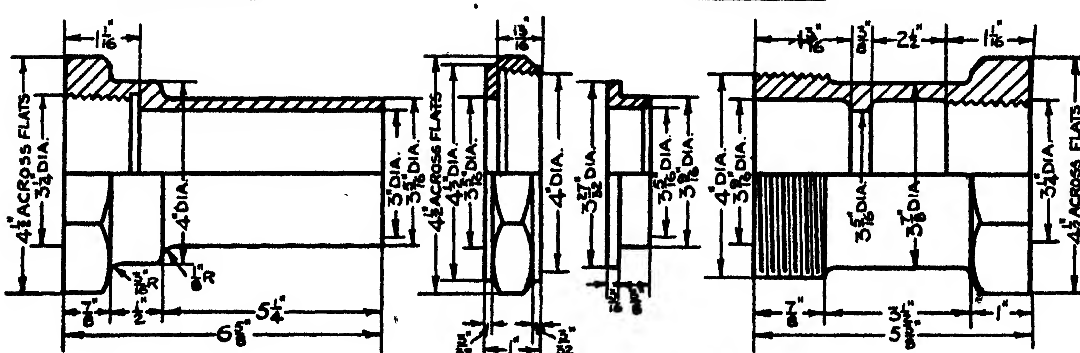


FIG. 103c – EXPANSION JOINT

3" DIA. 3" TRAVERSE
END TO END, OPEN $10\frac{5}{8}$"

ALL THREADS 11 T.P.I.

MATERIAL:-G.M. (NOT TO SCALE)

FOR STEAM WORKING PRESSURES UP TO 100 LBS □"

fig. 101. Such glands have many applications; in hydraulic work, steam engines, compressors, etc., and examples can be seen in Chapter XII. Packing consists of some fabric, resistant to the fluid, with a resilient backing and often a strengthening medium. Fig. 102 shows a typical packing which is made in lengths and cut off to fit the job; it consists of asbestos cloth with heat-resisting rubber stiffened with white metal sheeting. For higher pressures metallic packing is used, the white metal packing being reinforced by coiled springs or metal rings. Some of the simpler points on the design of valves for fluids are discussed in Chapter XII, page 147.

EXERCISE XI

(1) Make a freehand drawing of the arrangement by which the following pipes may be coupled: (*a*) copper pipe $\frac{3}{4}$ in. bore, (*b*) wrought iron pipe 2 in. bore, (*c*) 12 in. cast iron pipe.

(2) Sketch and describe the function of: (i) a hat ring, (ii) a U ring as applied to a $1\frac{1}{4}$ in. spindle.

(3) Make a single line freehand drawing of a pipe run to include the following: (i) a 45° bend, (ii) a tee, (iii) a Y branch, (iv) a valve, (v) a plug.

(4) Make an arrangement drawing of a roller support for a 6 in. pipe main similar to fig. 96, bracketed to a 9 in. rolled steel stanchion.

(5) Prepare a detail drawing of the roller and support bracket drawn in question 4.

(6) Make an arrangement for a suspension for a single 3 in. pipe main.

(7) Two ends of a steam main 7½ in. outside diameter are joined by a horseshoe expansion bend. The main has welded flanges 12 in. diameter, ⅞ in. thick, and the ends are 7 ft. apart. Draw a detail of the loop. Flanges to have 12 holes for ⅞ in. diameter bolts on 10½ in. p.c. diameter. Dimensions of bend: A 6 ft. 8 in., B 7 ft. 6 in., C 2 ft. 0 in., E 1 ft. 6 in. Scale ½ in. to 1 ft.

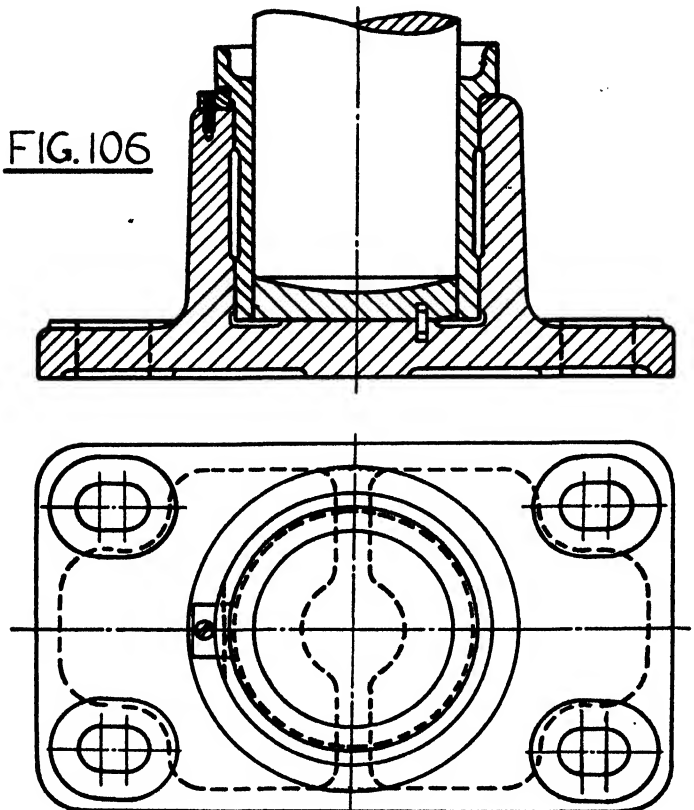
(8) Fig. 103*a* gives particulars of a housing for a Victaulic joint to suit the shouldered 4 in. tube shown. Make an assembly drawing showing a sectional end elevation on centre of pipe and a view looking along the axis of pipe.

(9) Fig. 103*b* gives details of a stuffing box for a 1½ in. shaft. Make an arrangement drawing with schedule.

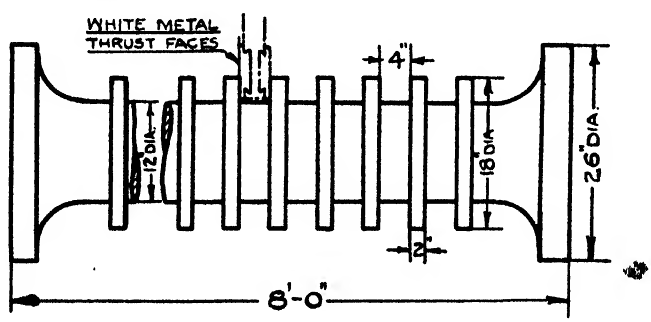
(10) Make an assembly drawing of the expansion joint (fig. 103*c*) with joint in its full open position.

(11) Make an arrangement drawing showing a half section and half outside elevation of a coupling (fig. 99*b*) for a 3 in. pipe (outside diameter of pipe, 3½ in.).

FIG. 106



FOOTSTEP BEARING FOR 4" DIA. SHAFT



THRUST SHAFT FOR MARINE PROPELLER

FIG. 107

placing the bush. For easier mounting on irregular surfaces the base is relieved, leaving a narrow fitting strip all round.

Vertical shafts are uncommon in ordinary transmission of power, but they often occur in machine practice; for example, in mixing equipment for paper-making and pulping, in swing bridges and turntables, and in textile machinery. A simple footstep bearing with a thrust pad for a vertical shaft is shown in fig. 106. The small plate in the groove at the top prevents the brass rotating. Split bearings of this type are used also to facilitate erection, especially when a heavier load necessitates extra thrust faces, which are provided by a series of collars or flanges.

Although vertical shafts are uncommon, an axial thrust along a horizontal shaft is very frequently met, and suitable thrust faces on the bearing must be provided (fig. 107).

STANDARD LINE SHAFTING AND BEARING EQUIPMENT

For ordinary transmission purposes, such as for line shafting, standard bearings or pedestals are mounted at intervals as required, supported either from the building wall or from overhead girders. Standard equipment for mounting bearings is shown in fig. 108. Similar equipment may be used for plain bushed bearings, but ball and roller bearings are much more efficient (see page 90).

To facilitate the process of alignment with the shaft axis it is convenient to mount the bearing in a separate housing as in fig. 108 *a*, *b*. The housing may be moved by adjustment on the screws. Fig. 109 shows a part detail of a housing.

REDUCTION OF THE FRICTIONAL LOSSES

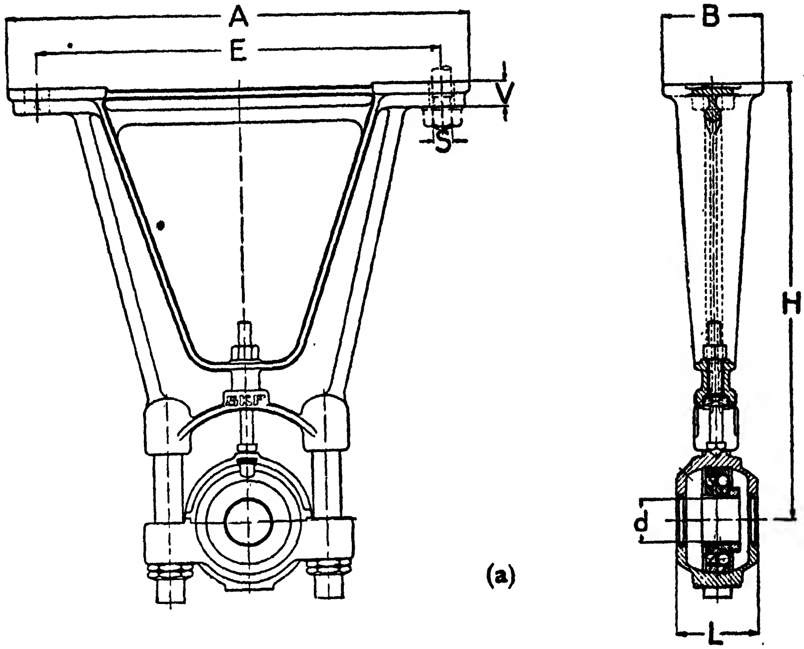
As the load on a bearing and the speed of the shaft increases, the frictional losses tend to increase also, and to avoid undue loss and generation of heat, better bearing surfaces are necessary. A great reduction in friction is effected by providing a lining of a bearing material such as one of the many "white metal" alloys (consisting principally of tin, lead and antimony). These alloys have a low melting point, and are poured into dovetail grooves in the bearing, and on solidifying are machined to suit. White metal bearings are used frequently on such varied work as locomotive axle boxes, automobile connecting rods and machine tool bearings. Examples of white metal surfaces are given on pages 137–8, 148, figs. 175, 176, 189, 190.

LUBRICATION

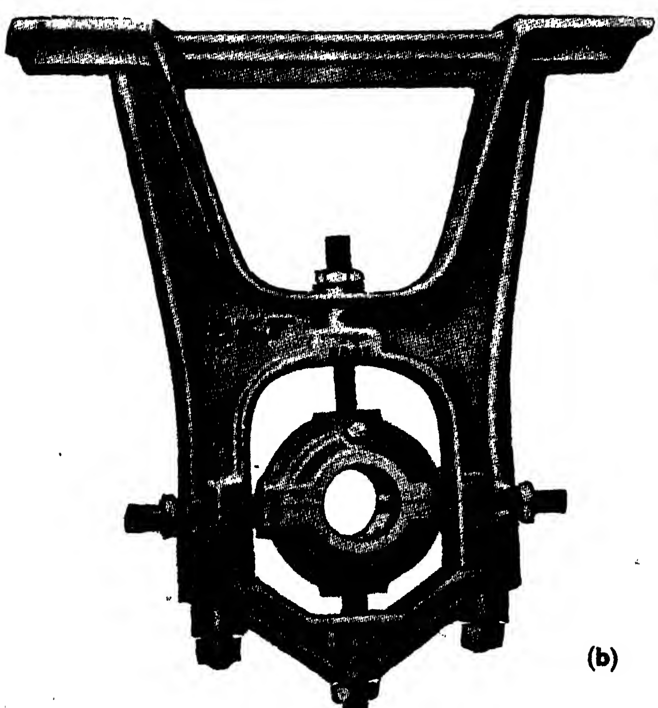
In addition to providing the most suitable bearing surface, a further improvement is made by introducing a thin film of oil or grease between the surfaces. The provision of oil grooves and a reservoir of oil was mentioned previously in connection with the Plummer block (fig. 105). To overcome the need for frequent replenishing with oil, lubricators are often used on bearings. The simplest type is the drip lubricator, a glass container with a stem fitting to suit the bearing cap. A needle plunger controls the speed of oil flow. Grease cups, or Stauffer lubricators, are also used extensively. The grease is expelled by screwing down the cap, or by a spring-loaded plunger. Fig. 110 shows these two types.

Ring Lubrication. An effective system which is often used on bearings in machinery as well as on standard pedestals, provides gaps in the upper half of the brass, in which rings run loosely on the shaft. The rings hang with their lower portions immersed in oil, and in rotation pick up a supply of oil which is transferred to the top of the shaft. The pedestal is designed to contain an oil well for the rings below the gaps in the journal. Fig. 111 shows a simple bearing of this type.

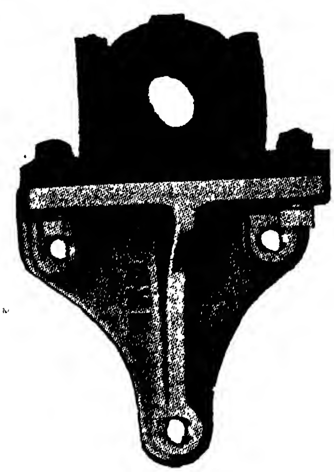
Forced Lubrication. Research has shown that when there is a very small clearance between the shaft and journal,



(a)

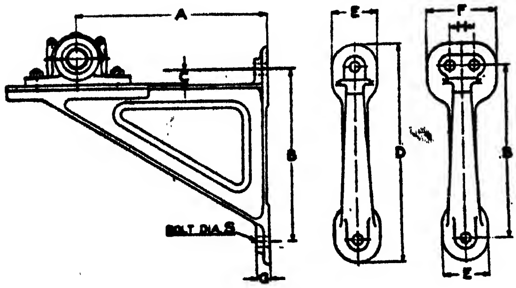


(b)

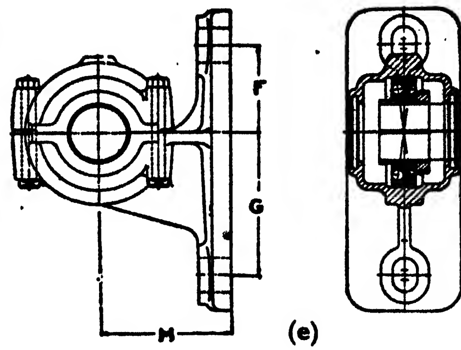


(c)

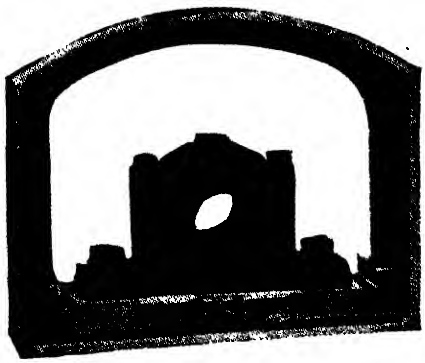
FIG. 108



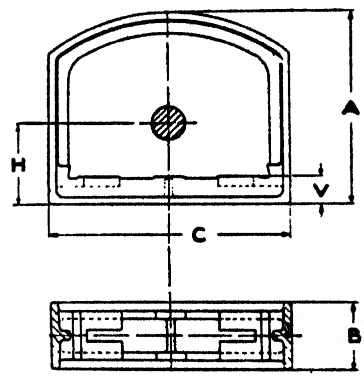
(d)

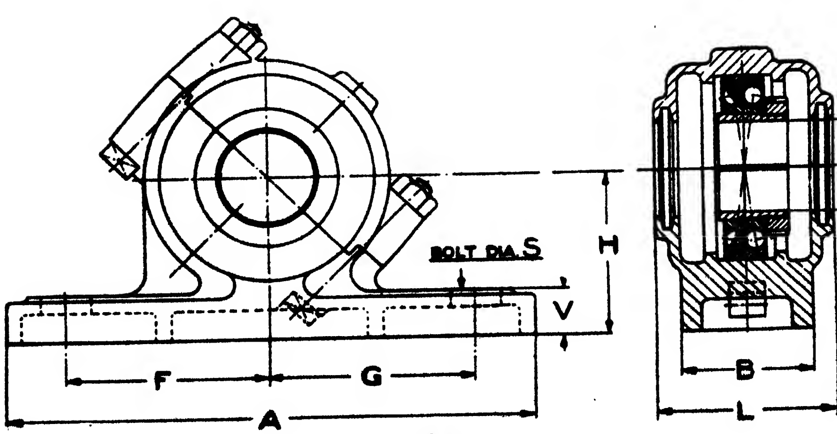


(e)



(f)





(g)

FIG. 108 (*continued*)

(*Fig.* 108 *by permission of Messrs. The Skefko Ball Bearing Co. Ltd.*)

lubricant introduced through a small hole in the bearing is carried round by the shaft and at high speed forms a continuous film of lubricant all round the shaft. This most efficient system is used on automobile and machine tool bearings, and in many other applications. The oil is pumped from a common oil sump to several bearings. Fig. 112 shows a pump and part of the forced lubrication system applied to a grinding machine slide. The action of the pump is very simple; the tappet rising under the action of the spring reduces the pressure and so lifts the lower ball valve. As the descending tappet closes the lower ball valve the oil is forced past the upper ball valve into the oil supply pipe.

Crankshafts and connecting rods provided with oilways for this system of lubrication are shown in figs. 181, 176, pages 143, 138.

Sealing Rings and Oil Throwers. When a liberal oil supply is provided it is both

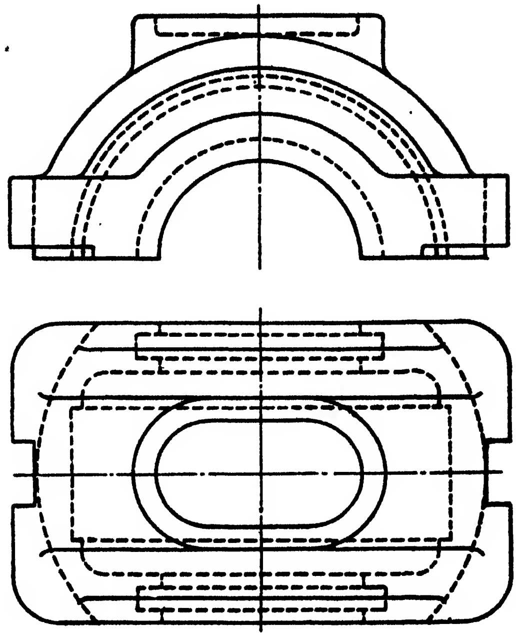


FIG. 109

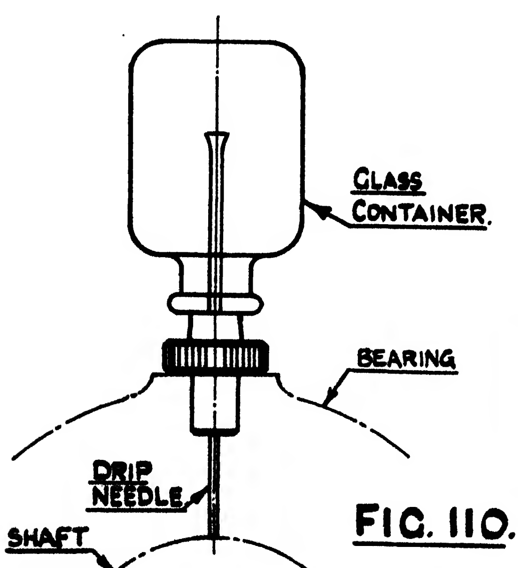
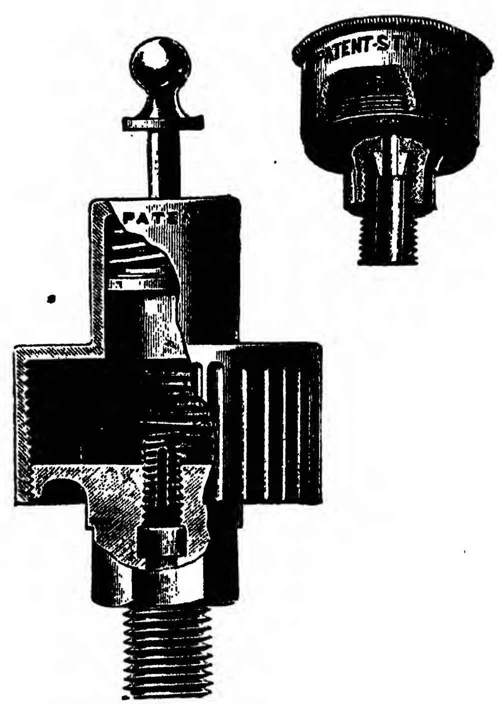


FIG. 110.

"NEEDLE" LUBRICATOR.



(*Fig.* 110 *by permission of Messrs. Buck & Hickman Ltd.*)

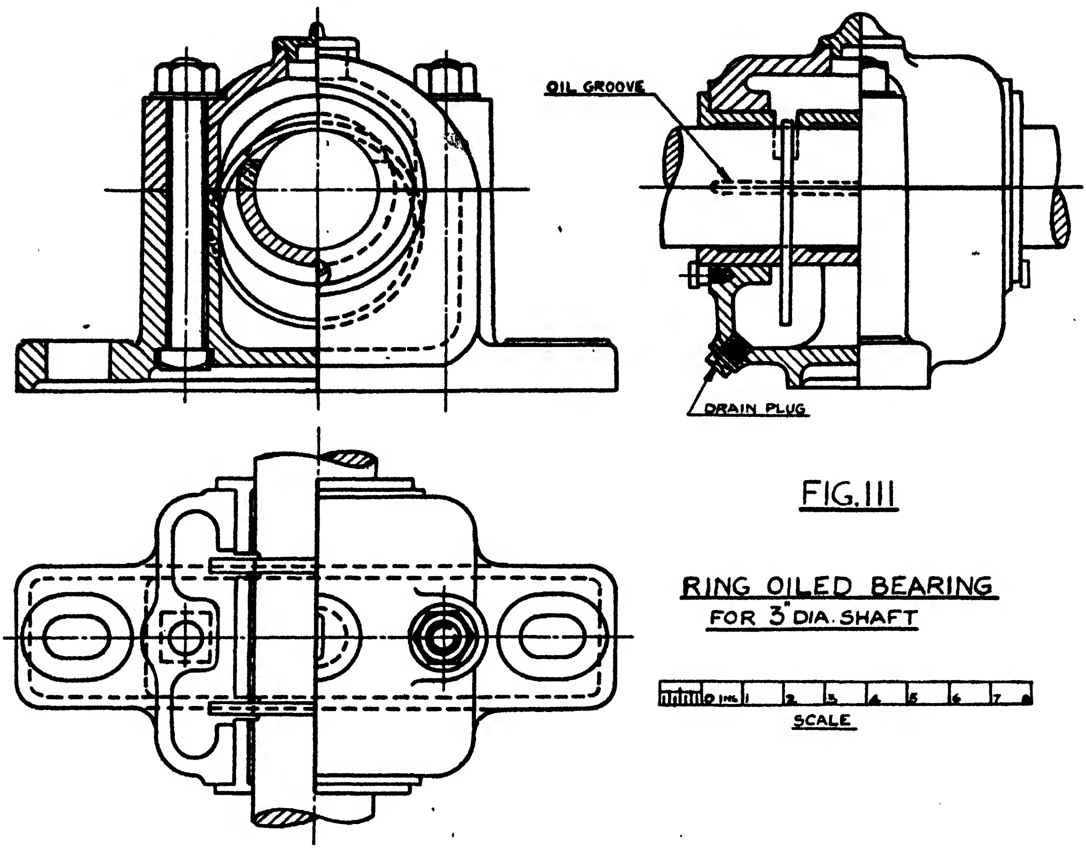


FIG. 111

wasteful and inconvenient to allow the lubricant to work along the shaft. To prevent this action, oil seals are fitted in the journal, and in some cases oil throwers provided on the shaft. The latter consist of a thin flange which deflects the creeping oil back to the shaft. Small grooves round a shaft also serve as an oil trap (see figs. 181, 204, pages 143, 157). The simplest oil seal consists of a felt ring fitted into a tapered groove, the felt wiping easily on the shaft (fig. 113*a*). Where this is insufficient, a seal as shown in fig. 113*b* is used. The packing exerts an even pressure on the shaft by the action of the spring, whilst the casing holds the packing and spring and makes a compact unit. Such a seal not only retains the lubricant but also excludes water and dirt.

Oil Impregnated Bearings. A recent development in bearing design is the use of bearings made by subjecting bronze powder to pressure in a die, and impregnating the powder with a large quantity of lubricant which is absorbed by the porous metal during the process. The bearings are die pressed accurately to the finished sizes, and give long efficient service. Fig. 114 shows typical bearings, and the accuracy obtainable.

BALL AND ROLLER BEARINGS

It has been proved that a smooth hard surface will roll over a similar surface more easily than it will slide. This fact is used to provide bearings having extremely low frictional losses, even at high speeds with heavy loads, by running on hard chrome steel balls or rollers,

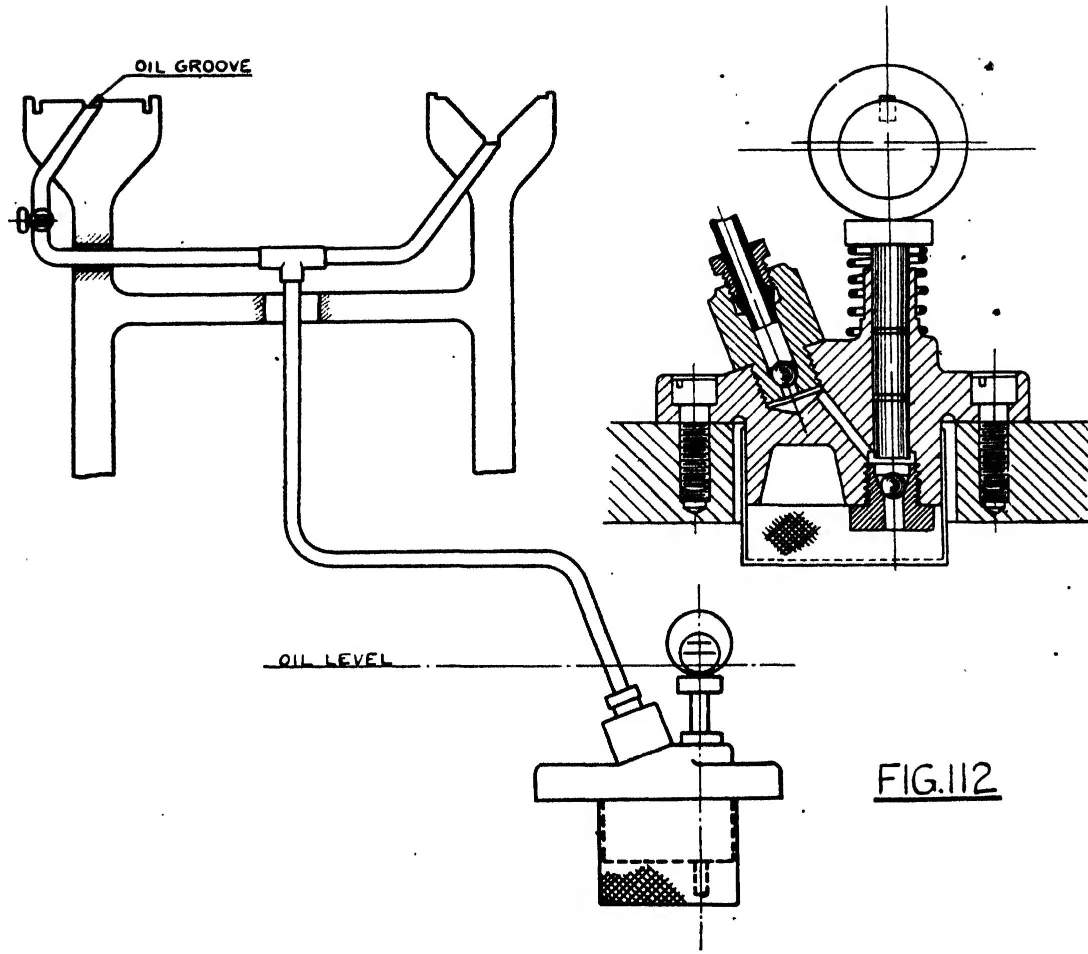


FIG. 112

(*Fig. 112 by permission of Messrs. The Churchill Machine Tool Co. Ltd.*)

carried in cages, in specially prepared rings or "races," the construction being of a very high standard of accuracy and finish to give the best results. There is a great variety of types of ball or roller bearings, made to suit varied conditions of load and speed. The excellent results obtained are due to the very high standard of accuracy and finish maintained in the manufacture, but the efficient working can be marred by careless mounting.

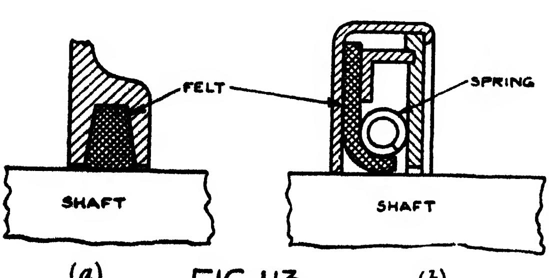
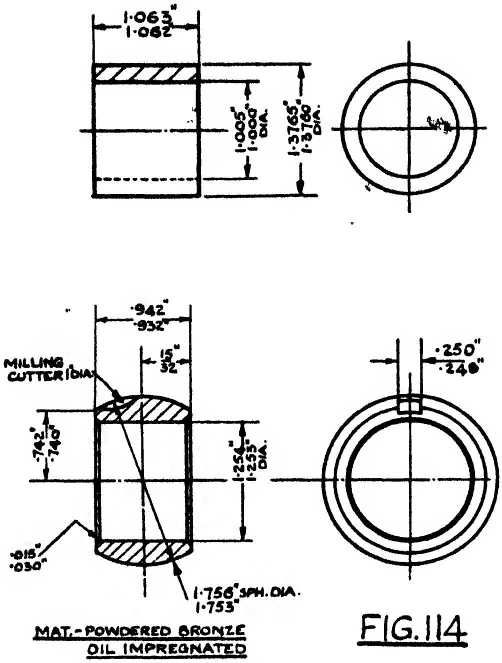


FIG. 113

Ball bearings are used where the loads are not exceptionally heavy for the size of journal, whilst for heavier work or shock loads the roller bearing is used. A roller bearing will take a very slight occasional end thrust, or special deep groove ball races may be used for this



(*Fig.* 114 *by permission of Messrs. The British Bound Green Bearing Co. Ltd.*)

purpose. If the thrust is a regular condition and is only light compared with the journal load, taper rollers, in which the thrust is taken on the cone surface of the cup, are more satisfactory. For thrust bearings, the balls or rollers are arranged to run in suitable grooves in flat discs. Both ball and roller bearings may be assembled in spherical housings which make the bearings self-aligning.

Examples of these types are seen in figs. 108 and 115–118. The bearings in fig. 108 are all self-aligning ball bearings mounted on a split taper sleeve. A similar bearing is used on the shaft, fig. 115*a*, with two plain ball bearings in the pulley hub. Taper roller bearings at the work end of the headstock mounting take both radial and thrust loads (fig. 115*b*), and heavy loads necessitate the use of a plain roller bearing at the other end. A footstep bearing from a paper-making machine is shown in fig. 116, where the radial load is taken by the self-aligning roller bearing and the thrust by the bearing on a spherical seat.

The application to automobile practice is shown in the mountings of fig. 117. A roller bearing takes the main journal load on the front hub. The thrust on the front axle swivel pin (fig. 118) is taken by the ball thrust bearing, while on account of limited space needle roller bearings are used at the lower end.

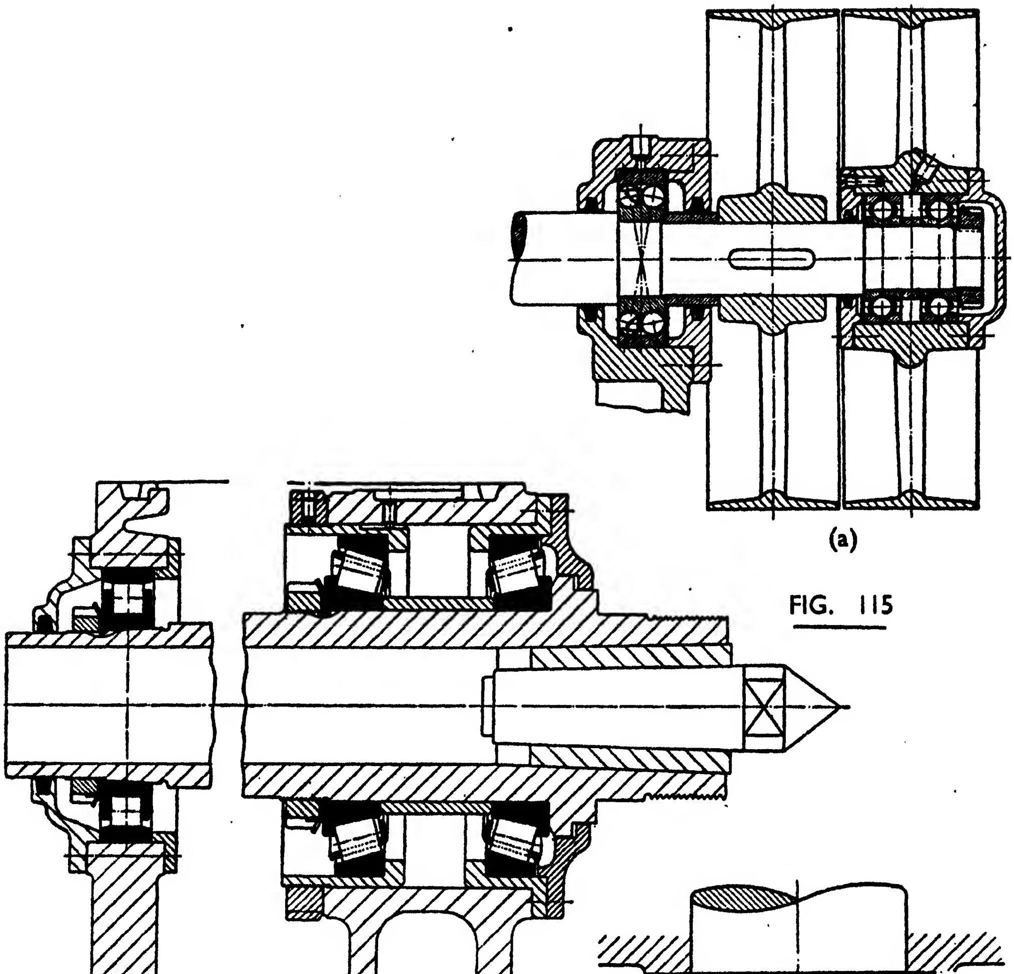
The Mounting is a very important matter and no general rule can be given to suit every case; as a guide, however, it is usual for the revolving race of journal bearings to be a tight fit, and the stationary race a push fit in their housings. The race is held up against a locating shoulder by means of a nut. Care must be taken that the clamping faces do not overlap the race; nipping of the rollers is liable if the clamping face exceeds the bottom diameter of the track, especially if the faces are not machined smooth and square. To mount a thrust race, the revolving race should be tight on the running shaft, and all the thrust faces square with the axis.

The mounting is completed by a suitable closure which is designed to seal the bearing and retain the lubricant, and, in certain instances, to locate the shaft. Sealing devices are necessary as in the case of plain bearings. The felt washers are used, and often additional labyrinth paths when dirty or wet conditions of service are met. The student should observe the mounting and sealing in the examples shown in figs. 115–118.

EXERCISE XII

(1) **The bearing bracket shown in fig. 119 was found to wear badly. Redraw with suggested improvements in the design without the use of ball bearings.**

(2) **Prepare an assembly drawing of a footstep bearing for a 3 in. diameter vertical shaft, giving half sectional front elevation and a plan. Give a schedule of parts and material.**



(a)

(b)

FIG. 115

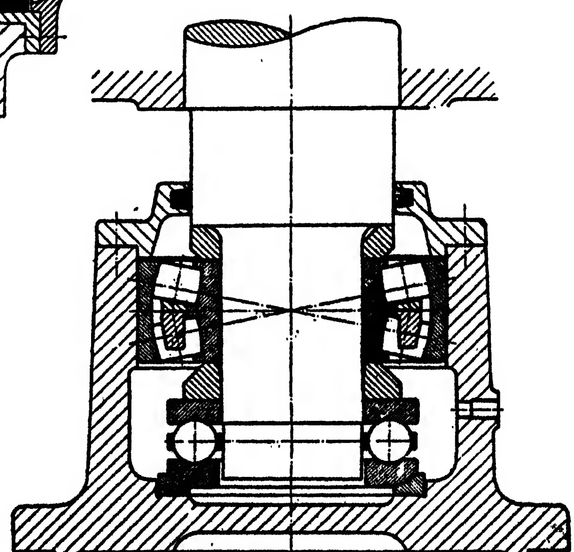


FIG. 116

(*Figs.* 115 *and* 116 *by permission of Messrs. The Skefko Ball Bearing Co. Ltd.*)

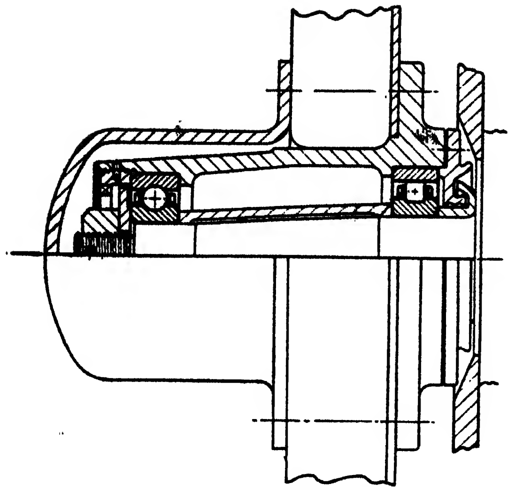


FIG. 117

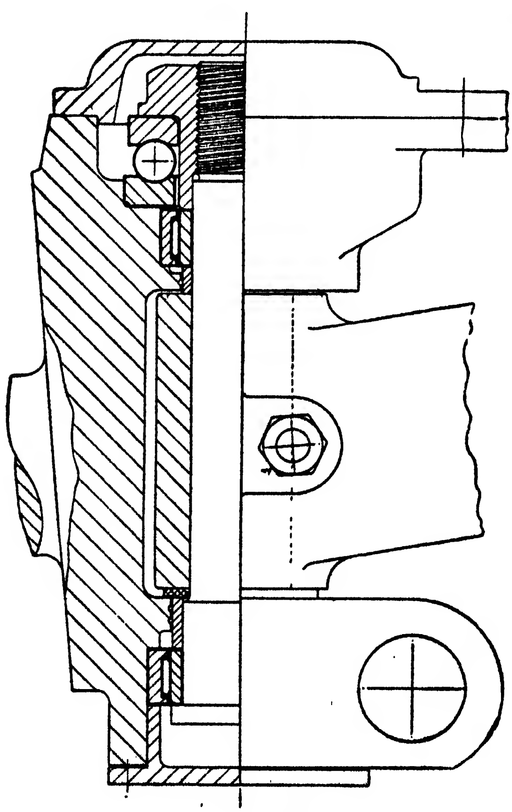


FIG. 118

(Figs. 117 and 118 by permission of Messrs. The Hoffmann Manufacturing Co. Ltd.)

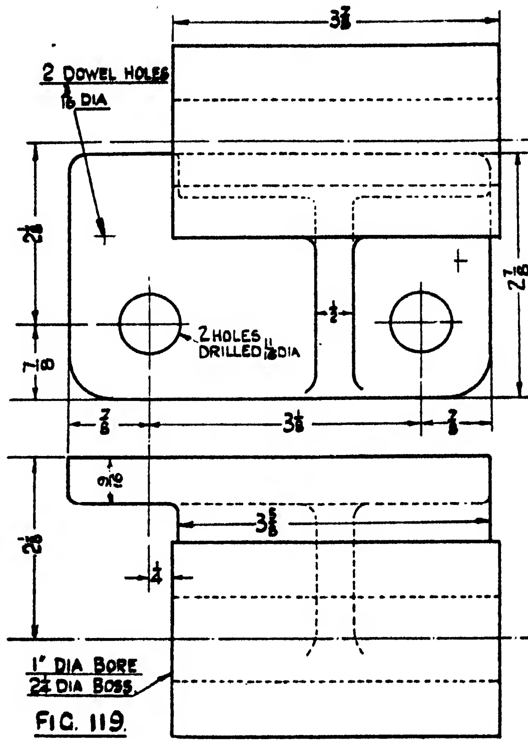


FIG. 119.

(3) Make an arrangement drawing of a simple Plummer block for a 3 in. shaft showing three views in half section.

(4) Detail the base and cap of the pedestal (question 3) giving full dimensions. Give sectional views as necessary.

(5) A housing suitable for a ball bearing in a sling hanger is shown in fig. 109, page 89. Design a housing to suit a ball race 4⅛ in. outside diameter and 1 $\frac{1}{16}$ in. wide, for a 2 in. diameter shaft in a hanger as shown in fig. 108*b*.

(6) The bearings of a machine tool headstock are outlined in fig. 120 with the machine spindle. Make an arrangement drawing of the bearings allowing for adjustment.

(7) Make a detail drawing of the base and of the cap of the ring oiled bearing shown in fig. 111.

(8) Study the mounting of the ball bearing in figs. 108*e* and *g*, then prepare an arrangement drawing of a ball bearing pedestal similar to that shown in the wall box, for a 3 in. diameter shaft. Allow recess for the bearing 7 in. diameter by 1⅜ in.

(9) Make a detail drawing of the hanger, fig. 108*a*, to the following dimensions: A $21\frac{5}{8}$ in., B $4\frac{3}{8}$ in., E $18\frac{7}{8}$ in., H 20 in., L $3\frac{3}{4}$ in., S $\frac{3}{4}$ in., V $1\frac{1}{8}$ in., for shaft 2 in. diameter. Scale half full size.

(10) What precautions are necessary in mounting ball and roller bearings? Sketch a mounting for a shaft having a roller bearing at one end and a ball bearing at the other.

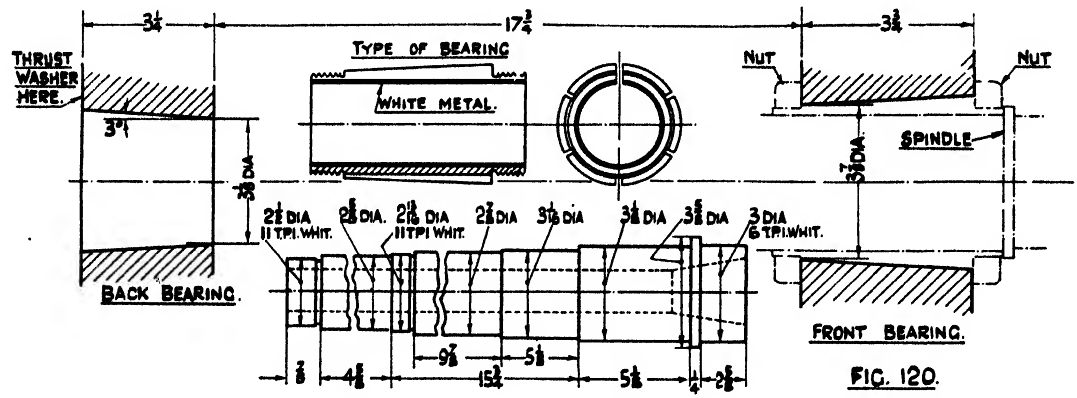


FIG. 120.

Chapter IX

MECHANICAL TRANSMISSION OF POWER

In every mechanical process transmission of motion from a prime mover or a shaft to another shaft is necessary. The movement may pass directly from shaft to shaft or by intermediate components such as pulleys, gears or sprockets. A study of the standard practice in various contingencies will enable the student to design for particular requirements.

KEYS AND SPLINES

The tightness of fit of the shaft in a bore is usually insufficient to secure a wheel, flange or pulley. An early expedient, the use of a square shaft, is inconvenient to manufacture with precision in fit. A simpler device was found by driving a small piece of steel between the shaft and the bore, and this is now the standard practice, *viz.*, a key. Fig. 121 shows three classes of key.

The saddle key is suitable for very light loads only, relying entirely on the friction between the shaft and the key. The flat key is a little stronger as there is some wedging action, but the usual form is the sunk key fitting into a keyway machined in both shaft and hub. The key is always parallel in width, the keyway being machined in the shaft by a side and face cutter on a horizontal, or by an end mill on a vertical milling machine. When drawing a keyway this point should be remembered (see fig. 122). Keys are sometimes tapered in thickness, in which case the taper is 1 in 100 (or about $\frac{1}{8}$ in. per foot of length) and the given thickness of the key refers to the larger end. Taper keys are used on pulleys and flywheels, but with modern production in large quantities, the keys are usually parallel.

A key is always fitted to the keyway in width, but a parallel key is not a fit on its depth, so that it does not locate the component axially. A taper key, however, fits the taper keyway tightly and so does fix the component. The proportions of standard keys are given in Table IX, page 175.

Other types of key are used for particular purposes (fig. 123). For very heavy drives, such as in a rolling mill, two square keys are used, whilst for a component which must be free to slide along the shaft and still drive by means of a key, a **feather key** is fitted. The **Woodruff key** is frequently used in such work as automobile and machine tools. It easily aligns itself, and is very suitable for a tapered shaft, but the key slot weakens a shaft considerably.

When a taper key is used, it can be removed by driving out from the small end. If this is not accessible, a key having a head must be used; the removal can then be effected by driving from the inner side of the head. These keys are known as **gibs.**

A very robust design is that in which the key is an integral part of the shaft, but until the development of special key milling and broaching machines this has not been practical. The arrangement is now quite common, especially on shafts which slide in a component; instead of one key, four or more are used, and the shaft is called a **splined shaft.**

COUPLINGS

A coupling is an arrangement whereby rotary motion passes directly from the end of one shaft to the end of another.

(1) RIGID COUPLINGS

These transmit the rotation without any slipping. The simplest type is the muff, a sleeve passing over the end of and

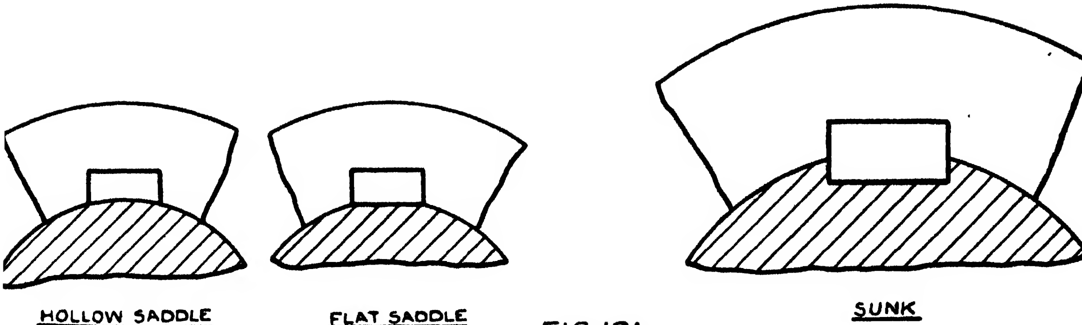


FIG. 121

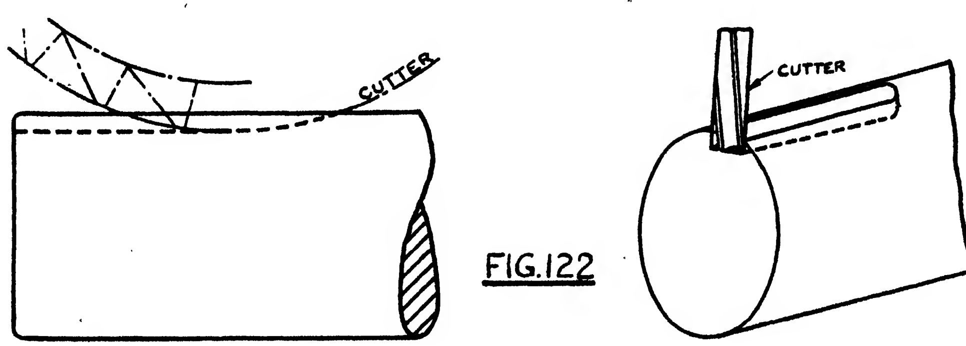


FIG. 122

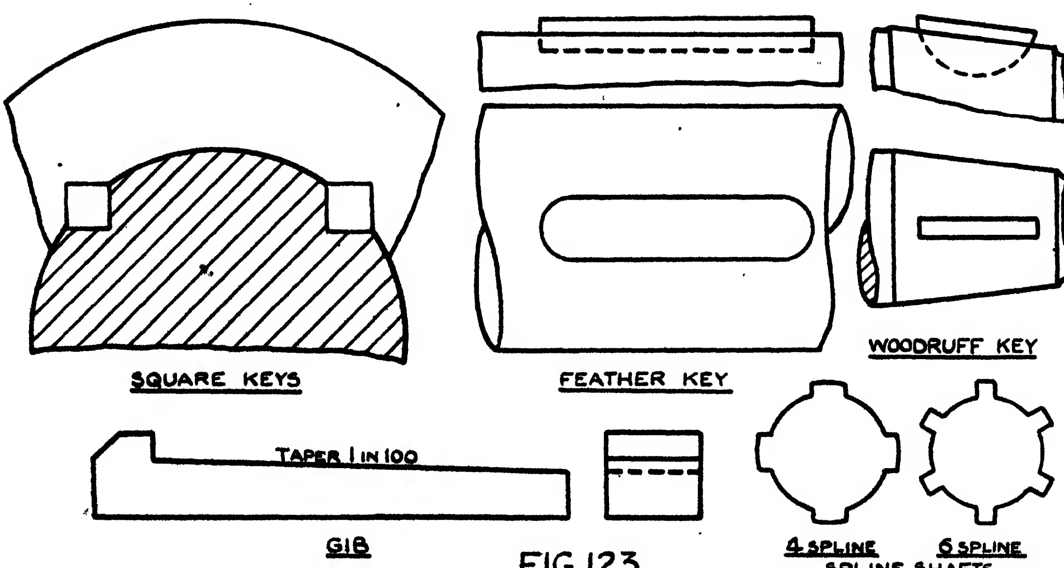


FIG. 123

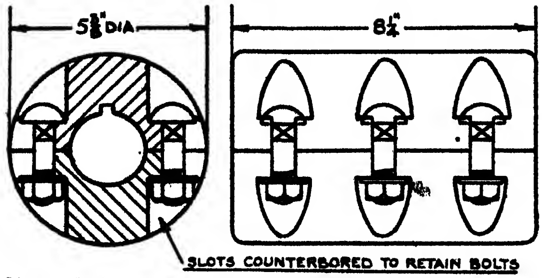
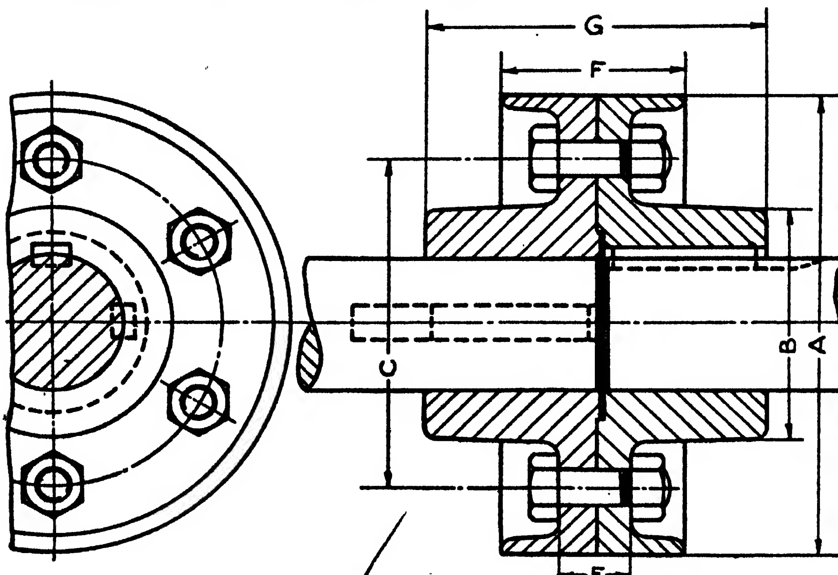
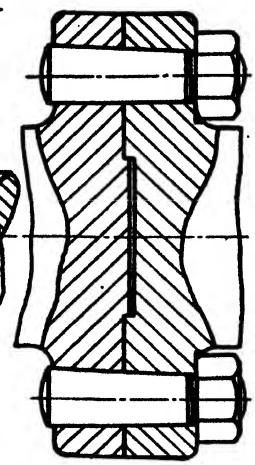


FIG. 124a – SPLIT MUFF COUPLING

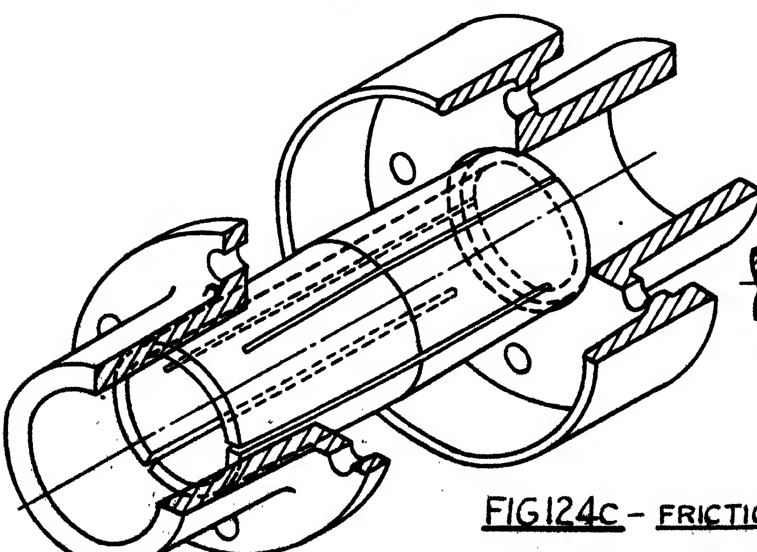
Shaft Diam. in.	A	B	C	E	F	G	Bolts
2	$7\frac{3}{4}$	$3\frac{5}{8}$	$5\frac{3}{8}$	$1\frac{1}{8}$	$2\frac{1}{2}$	$3\frac{3}{4}$	$\frac{5}{8}$–4
$2\frac{1}{2}$	$9\frac{1}{8}$	$4\frac{3}{8}$	$6\frac{5}{8}$	$1\frac{1}{8}$	$2\frac{7}{8}$	$4\frac{3}{4}$	$\frac{3}{4}$–4
3	$10\frac{1}{4}$	$5\frac{1}{4}$	$7\frac{1}{2}$	$1\frac{1}{4}$	$3\frac{1}{8}$	$5\frac{3}{4}$	$\frac{3}{4}$–6
4	$12\frac{7}{8}$	$6\frac{3}{4}$	$9\frac{1}{2}$	$1\frac{1}{2}$	4	$7\frac{1}{2}$	$\frac{3}{4}$–6





MARINE TYPE FLANGE COUPLING FOR 10" DIA. SHAFT

FIG. 124b – FLANGE COUPLING FOR 3" DIA. SHAFTS



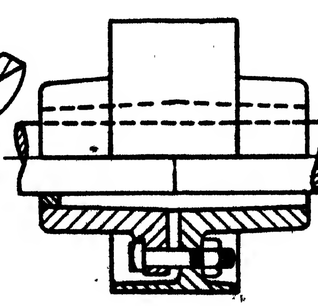


FIG. 124c – FRICTION COUPLING

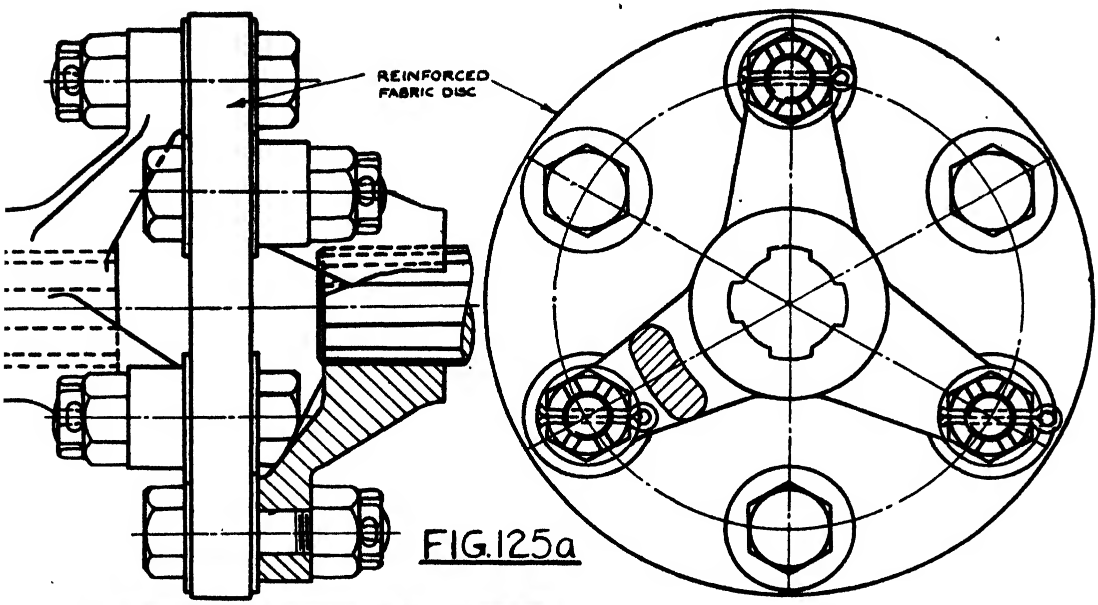


FIG. 125a

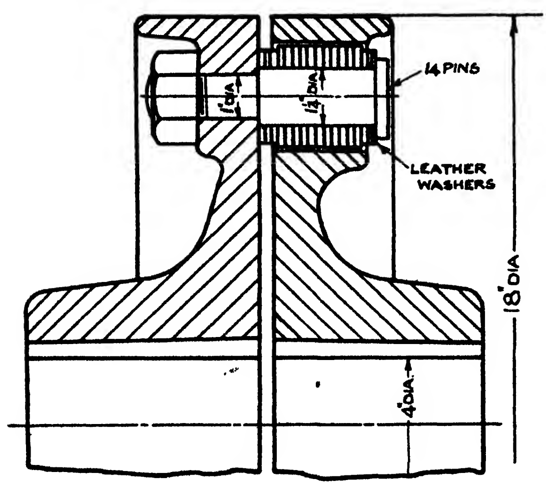


FIG. 125b

(Fig. 125b by permission of Messrs. Frank Wigglesworth & Co. Ltd.)

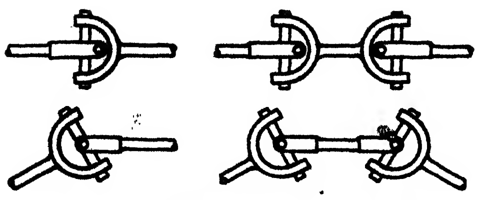
keyed to each shaft. The muff coupling is usually split as in fig. 124*a* to facilitate its passing over the ends of the shafts.

The flange coupling is more effective, as the load is transmitted partly by the key and partly by the bolts (fig. 124*b*). As a protective measure the bolt heads and nuts are shielded by a rim on each flange. Alternatively, the bolt heads and nuts are let into counterbored recesses in the flanges. The bolts should be a good fit in the bolt holes in order that the load is taken smoothly, without the impact which would take place if the bolts were in clearance holes.

There are several types of coupling in which the transmitting torque is taken by frictional grip of conical surfaces. Fig. 124*c* illustrates this type. In addition there are many neat patented devices for couplings, such as those which transmit the load through an endless belt encircling pins, or by a chain on sprockets on the flanges.

(2) FLEXIBLE COUPLINGS

In order to avoid undue load on the shaft it is often necessary to allow a slight slip when changes take place in the speed, such as when starting, or on accelerating. This may be achieved by transmitting through a resilient medium, such as rubber reinforced with a fabric. Fig. 125 shows two forms of flexible coupling. It will be noticed that although very slight axial displacement may be accommodated by the



SINGLE FIG. 126a DOUBLE

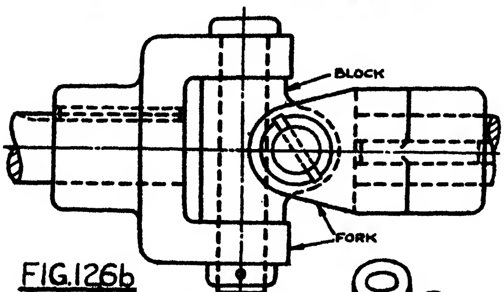
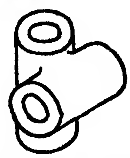


FIG. 126b

UNIVERSAL JOINT (BLOCK TYPE)



DETAIL OF BLOCK (REDUCED)

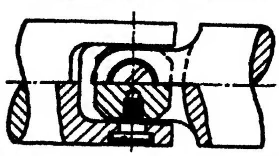


FIG. 126c

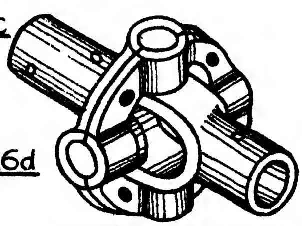


FIG. 126d

UNIVERSAL JOINT (RING TYPE)

flexible medium, this type of joint is essentially designed for shafts in alignment. There are, however, examples of flexible couplings of good design functioning satisfactorily when the shafts are at angles of 6° or 7°.

(3) SHAFTS OUT OF ALIGNMENT

Universal Joints. It is very often necessary to connect shafts when the axes intersect at an angle, the angle being variable; the Universal Joint, or Hookes Coupling, is used for this purpose. The rotation is not transmitted uniformly when a single joint connects shafts at an angle, but by doubling the joint exact uniformity is achieved (fig. 126*a*). Types of such joints are shown in figs. 126*b*–*d*; the student will notice several examples in machine tool and automobile work. To reduce losses due to friction, universal joints are often made with the coupling piece fitted with anti-friction rollers or balls. The transmission to the back axle of a car is of this type. Notice that needle rollers could be fitted round the pins of joint 126*d*.

Oldham Coupling. A coupling which is of technical interest, but not often used in practice, is the Oldham coupling (fig. 127), designed to connect shafts when the axes are parallel but slightly out of line. The connecting tongued disc needs free lubrication, which is rather difficult to achieve without totally enclosing the joint. It has been used for certain valve gearing on motor cycle work, and on various small mechanisms.

(4) INTERMITTENT TRANSMISSIONS

In order that a drive from a shaft may be engaged or disengaged as required, a **clutch** is inserted. There are many types of clutch, but all types consist of one member secured to the driving shaft, and another member attached to the driven shaft in such a way that it can move axially to engage, or be free from, the member fixed to the rotating shaft. A simple dog clutch (fig. 128*a*), which is suitable for slow running machinery, gives a positive drive (the lower figure for rotation in one direction only), but there are also various forms of friction clutch used in machine work and automobile practice which give some flexibility to the engagement (fig. 128*b*).

BELT, ROPE AND CHAIN DRIVES

When the axes of shafts do not intersect, the shafts may be driven by belt or by chains engaging wheels firmly secured to each shaft. Wheels used for belting are shown in figs. 158–9, page 124. The rim is usually "crowned," that is, made with a larger

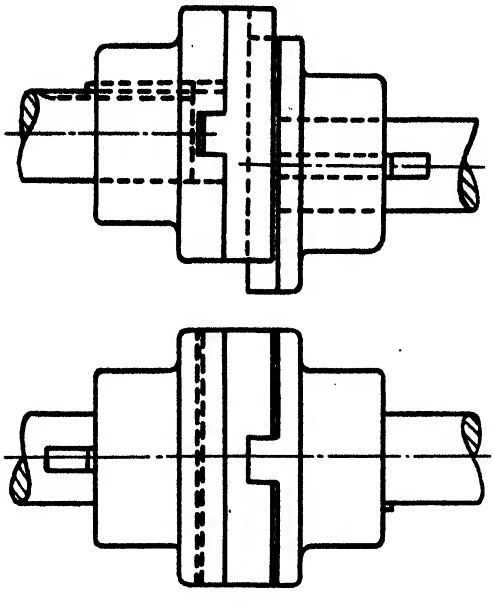
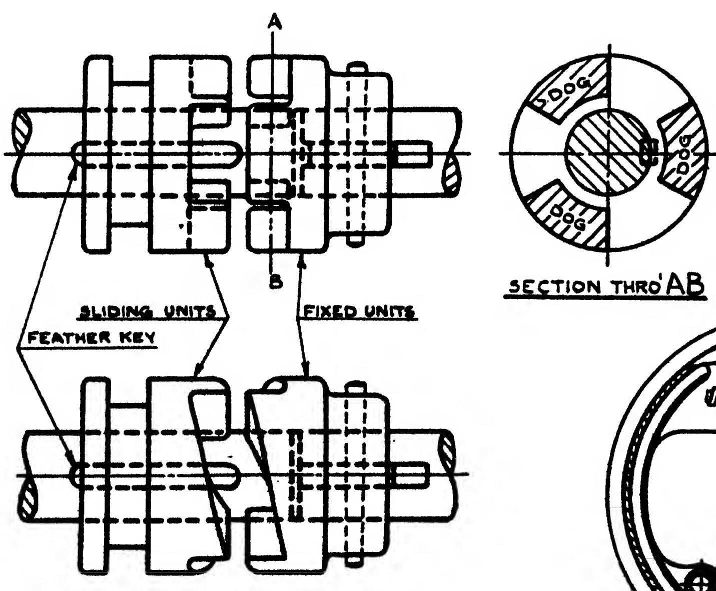


FIG. 127 - OLDHAM COUPLING

diameter at the centre of the wheel, as this enlargement helps to keep the belt on the pulley due to the fact that a belt always tends to climb to the largest diameter. Flat belts of leather or a canvas material (balata) are used extensively still, although the introduction of motorised drives to individual machines has reduced their application somewhat.

The speed of driving and driven shafts is inversely proportional to the pulley diameters and is not affected by distance between shafts. Speed reductions of 5 or 6 to 1 may be achieved, but when the difference of pulley diameters is unduly great the angle of lap on the smaller pulley is so reduced that the frictional grip is impaired, and slipping takes place. This is illustrated by fig. 129*a*, which also shows an open and a crossed belt drive. Crossed belts giving a reversal of direction of rotation should not be used for vertical belt drives.



FIGS 128a

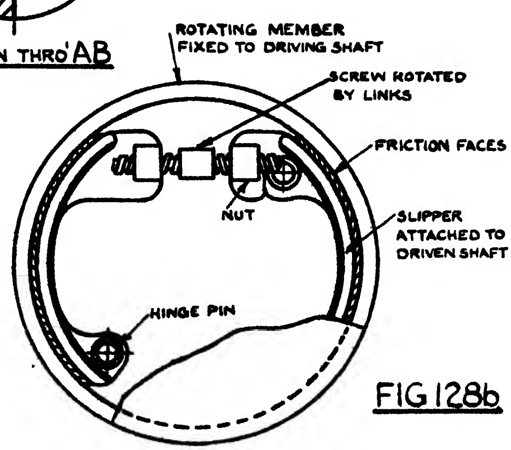


FIG 128b

(*Fig.* 128*b by permission of Messrs. Frank Wigglesworth & Co. Ltd.*)

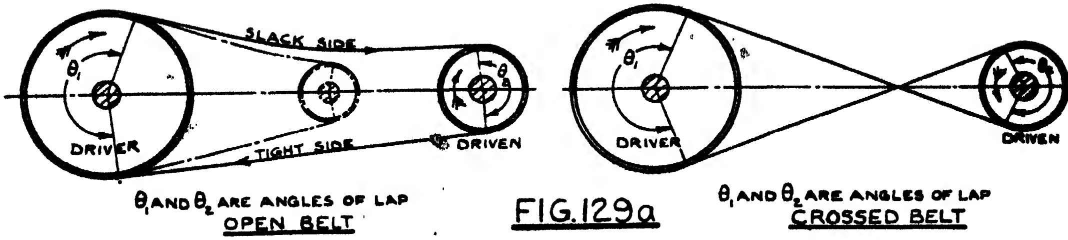


FIG. 129a

It is possible to connect shafts at an angle by belt, but in modern practice there is usually a more efficient alternative (*e.g.*, individual drive or spiral gears). It is essential for this type of drive that the part of the belt retreating from each pulley must be in the plane of the centre of width of the other pulley (*viz.*, C_1 must be over A_1, fig. 129*b*) and rotation must be in the one direction only.

Belt drives are very adaptable in giving a range of speeds, and convenient stopping and starting. To effect these changes a countershaft and striking gear is necessary. Fig. 130 shows an arrangement whereby a machine can be made to stop, or run at three different speeds, by means of fast and loose pulleys and speed cones. By providing a wider driving pulley on the main shaft and a further fixed pulley on the countershaft, reverse speeds can be obtained also.

The speed cone gives a variation in the ratio of driver to driven, and thus of the speed. A fast pulley is keyed to the countershaft so that when the driving belt is moved on to it, the fast pulley and countershaft rotate; the other pulley is free to turn on the countershaft, so that by moving the driving belt, the loose pulley rotates freely without turning the countershaft. Loose pulleys are sometimes fitted with ball bearings to ensure free running. See fig. 115*a*, page 93.

VEE BELTS

A common form of transmission, used up to about twenty years ago, was the rope drive; it is rarely, if ever, used now. The driving wheels had a Vee groove in

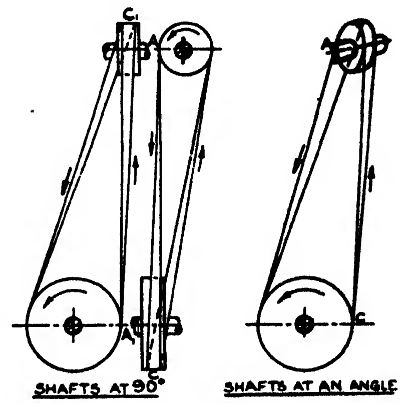


FIG. 129b

the rim, so that the grip was improved by the wedging action.

A more modern drive having similar characteristics is the Vee belt drive, in which pulleys with a Vee groove are driven by the Vee belts, moulded as endless loops from rubber reinforced with fibrous material (fig. 131*a*).

By increasing the number of belts it is a simple matter to transmit greater power. This form of drive is used extensively in all classes of machinery, transmitting anything from one-third up to about 450 h.p. In an emergency it is possible to continue to drive temporarily if one belt fails, when a number is used in one drive.

The frictional grip is so improved by the inclined sides of the groove that it is satisfactory to work with a smaller angle of lap than is possible with the flat belt. This is a very distinctive advantage, enabling greater speed ratios, or shorter centre distances, to be used efficiently. In calculating speed ratios,

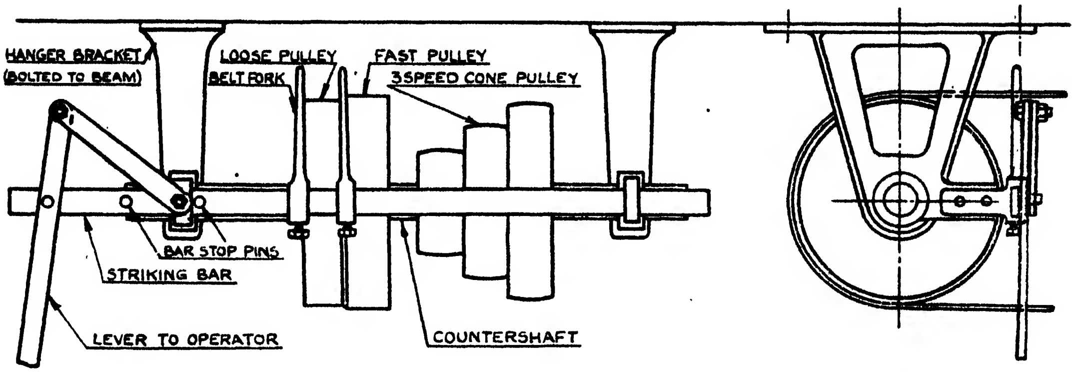


FIG. 130 – COUNTERSHAFT AND STRIKING GEAR (OVERHEAD TYPE)

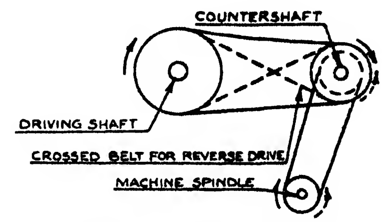


DIAGRAM OF A BELT DRIVE FROM MAIN SHAFT TO MACHINE

the pitch circle diameter of the pulley at the centre of the belt is used.

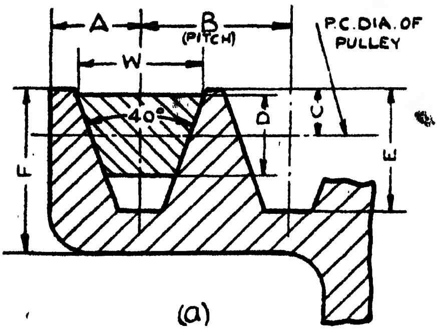
Vee belts driving from individual motors to one machine are replacing the common mainshaft, driving several machines through countershafts, to a very great extent. A variation of the speed ratio in a Vee belt drive may be effected by using special forms of pulleys in which the inclined Vee faces move apart, so causing the belt to run on different pitch circle diameters (fig. 131*b*).

CHAIN DRIVES

With any form of belt drive there is a certain amount of slip and elasticity, which in some cases is advantageous in avoiding excessive shock. A form of drive which is equally flexible is the chain drive, of which there are two or three types. It is very adaptable, and suitable for either horizontal or vertical shafts, giving a positive non-slip drive.

The great advantages of any chain drives are its compactness and flexibility and the ease with which, by the use of jockey sprockets, several drives may be effected by one chain, as shown in the scheme of fig. 132*a*. By increasing the number of chains more power may be transmitted; the selection of size and type of chain is made by considering the load and the speed of the transmission. The wheels used must be such that the arc of contact is not too small, usually 90° being the minimum which ensures that the load is shared by not less than three teeth at the pitch line. This, of course, limits the possible speed ratio with one pair of wheels, and the centre distance, but jockey sprockets can be used effectively to counter this, or greater ratios may be obtained by using a series of pairs of sprockets. Small sprockets are normally made in one piece, but larger sizes may be mounted on a separate hub (see fig. 134).

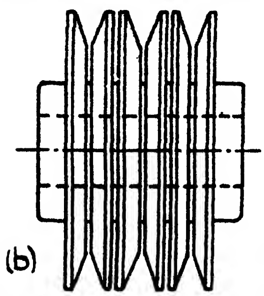
A roller chain drive, properly erected and maintained, makes very little noise, even at high speeds. The "inverted tooth" or "silent chain" is quieter still. The teeth, of the form shown in fig. 132*b*, slip with a wedge action into the tooth space and give an efficient drive even when the chain is slightly stretched. The chains are made up of rows of links side by side, each link of approximately $\frac{1}{8}$ in. thickness. This type of chain is very little used at the



SECTION OF VEE BELT & PULLEY RIM

W	1/2	21/32	7/8	1 1/4
A	7/16	9/16	11/16	7/8
B	5/8	3/4	1	1 7/16
C	3/16	1/4	3/8	7/16
D	5/16	7/16	5/8	3/4
E	9/16	11/16	15/16	1 3/16
F	13/16	1	1 5/16	1 5/8

DIMENSIONS IN INCHES



FIGS 131

(*Fig. 131 by permission of Messrs. Frank Wigglesworth & Co. Ltd.*)

present time, however. For efficient working, chains should be enclosed in an oil case and run through lubricating oil.

The adaptability of chain drives is illustrated by the application to remote control, for example, aeroplane controls.

GEARING

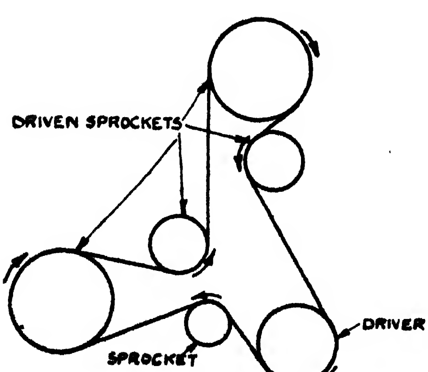
A very important method of transmission between shafts with axes which are comparatively close, by securing gear wheels to each, must be left for consideration in a more advanced book. The method of representing gear wheels in drawing office practice is shown in fig. 133. When using a gear drive the speed ratio is in inverse proportion to the number of teeth on the gears secured to the shafts. Gears produced by modern methods can connect parallel or inclined shafts very efficiently and quietly.

EXERCISE XIII

(1) Make an arrangement drawing of a friction coupling (fig. 124*c*) suitable for a 2 in. shaft, diameter over flange 7⅛ in., total length 7½ in., width of flange 3 in., with four bolts, ⅜ in. B.S.F.

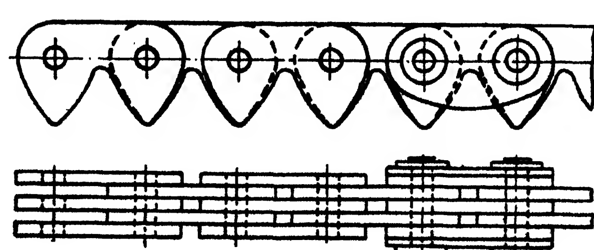
(2) Using the dimensions given in chart, draw a half sectional front and an end elevation of a flange coupling for a 4 in. shaft, half full size.

(3) A flexible coupling consisting of two spiders (fig. 125) with a fabric disc, connects splined shafts 2 in. diameter with six splines 0·50 in. wide, 0·10 in. deep. Boss diameter 3⅛ in., length 2 in., from fabric face to end of boss 2¾ in., fabric has six holes for ⅜ in. bolts on a



CHAIN DRIVE WITH JOCKEY SPROCKETS

FIG. 132a



CHAIN DRIVE (INVERTED TOOTH)

FIG. 132b

$6\frac{1}{4}$ in. p.c. diameter. Make an arrangement drawing showing a half sectional elevation through one of the spiders, and an end elevation.

(4) The drive to a mechanical testing machine is engaged by a claw coupling having three teeth in each member. Outer diameter of each member $2\frac{7}{16}$ in., overall length $2\frac{1}{2}$ in., shaft diameter $1\frac{1}{2}$ in., depth of teeth $\frac{11}{16}$ in. Make a working drawing of the sliding member.

(5) On a machine for making paper cartons, two vertical spindles $\frac{5}{16}$ in. diameter, are $\frac{3}{64}$ in. out of axial alignment. It is not possible to move the axis of either shaft to bring them into alignment. Show how the shafts may be coupled, and detail the coupling four times full size.

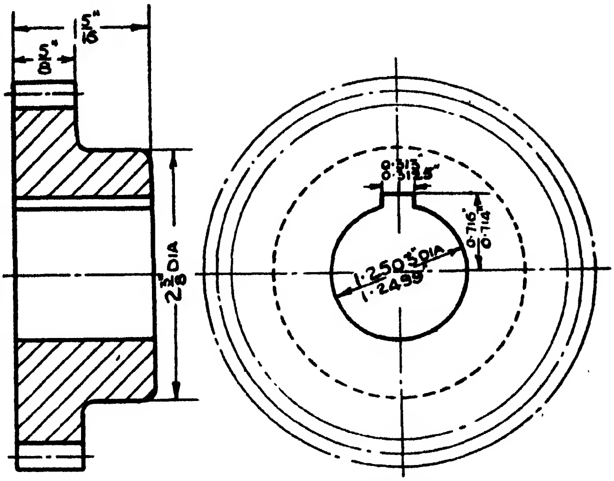
(6) For the automatic feed of a milling machine a spindle $1\frac{1}{4}$ in. diameter drives through another $1\frac{1}{4}$ in. spindle which has an axial movement of 20° on either side of the driving spindle axis. Design a suitable coupling.

(7) Detail each part of the coupling of question 6.

(8) The main drive shaft on a machine is to run at 120 revs. per minute and from this shaft an operating spindle is to be driven by a $\frac{1}{2}$ in. Vee belt at 300 revs. per minute. The pitch circle diameter of the main shaft pulley is 10 in., operating spindle $1\frac{1}{2}$ in. Make a detail drawing of the driven pulley.

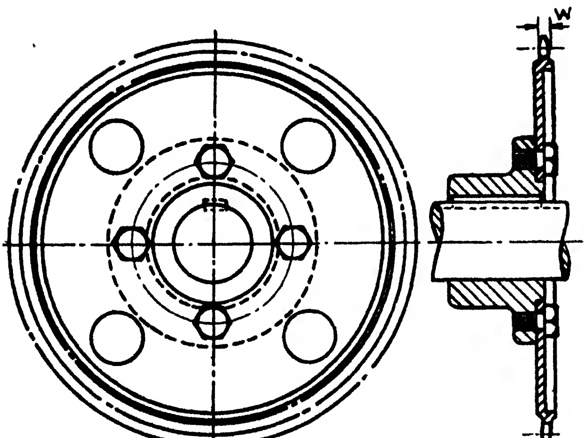
(9) The sprocket shown in fig. 134*a* was used to drive a spindle at 200 revs. per minute. The driving sprocket running at $62\frac{1}{2}$ revs. per minute had 15 teeth. It is required to increase the spindle speed to 225 revs. per minute. Detail a new sprocket and a suitable hub for a $1\frac{1}{2}$ in. diameter shaft.

(10) Make an assembly drawing of the cone coupling (fig. 134*b*), showing half sectional elevation and an end elevation. Allow taper of 2 in. on diameter per foot length.



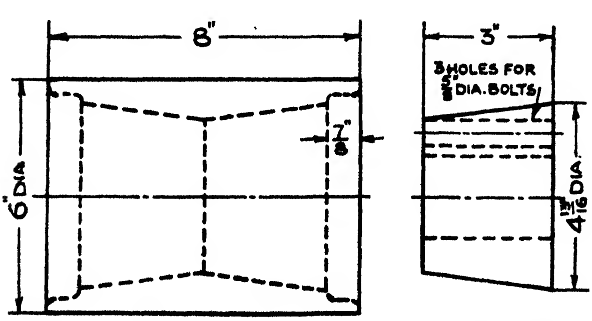
No. OF TEETH - 28 - 8 DIAMETRAL PITCH
P.C. DIAMETER - 3·500"
OUTSIDE DIA. - 3·750"
ROOT DIA - 3·2108"
NOTE - DIAMETRAL PITCH = No. OF TEETH / P.C. DIAMETER

FIG. 133



No. OF TEETH - 48 P.C. DIA. - 7·645"
TOP DIA. - 7·92" BOTTOM DIA. - 7·34"
WIDTH OF TOOTH W - ·176"

FIG. 134a - SPROCKET FOR ½" PITCH ROLLER CHAIN



COUPLING (1 OFF) CONE (2 OFF)

FIG. 134b - CONE COUPLING FOR 2" SHAFT

Chapter X

PRODUCTION PROCESSES

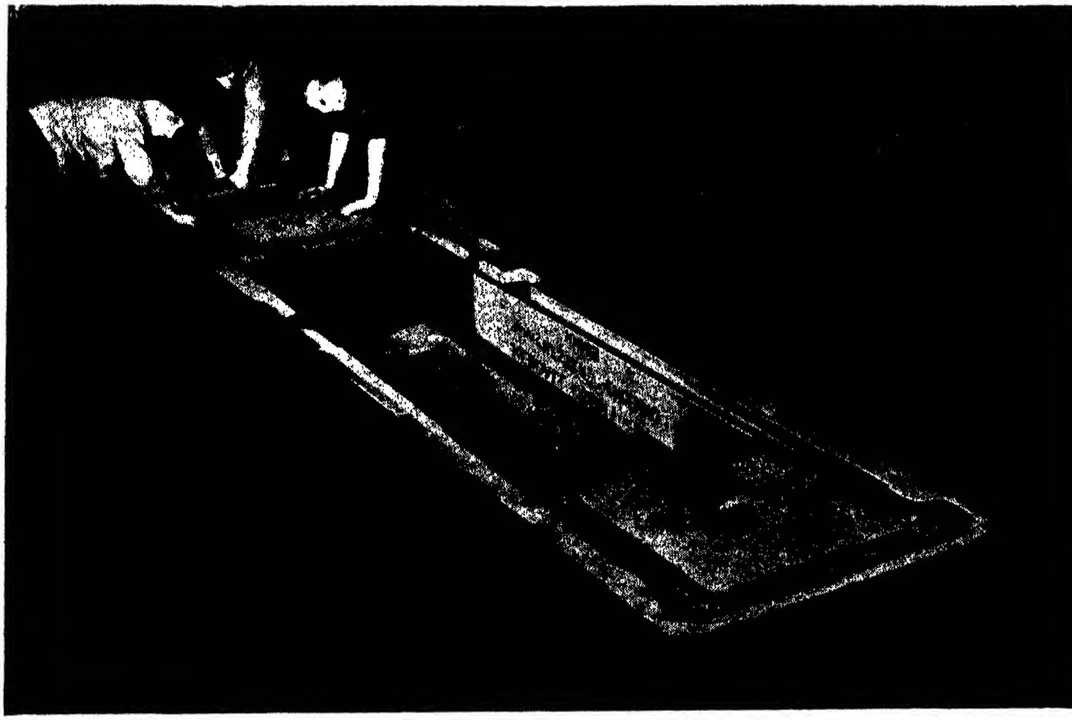


FIG. 136b

(*Fig.* 136*b by permission of Messrs. Kendall & Gent* (1920) *Ltd.*)

BEFORE a drawing can be finished intelligently, the draughtsman must consider how the component will be made. Since many students have little opportunity to study the production methods of all departments, a brief general outline is given in this chapter to assist in the comprehension of design points, and to show alternatives for a given detail. It will be appreciated that space prohibits a more complete treatment of a very wide subject, the salient features only being considered.

CASTINGS

To produce a casting, molten metal, such as iron, steel, brass or aluminium, is poured into a previously prepared sand mould, from which it is removed after solidifying. To make the mould, a pattern is needed similar in shape to the required casting, but it must be slightly larger, so that the finished casting, after cooling and contracting, will be correct in size. In making the pattern, a rule with graduations slightly larger than true scale is used. Patterns, which are usually of wood, must be smoothly finished, and so constructed that they may be drawn out of the mould.

Moulds are prepared in rigid iron moulding boxes which are made in various rectangular sizes. Fig. 135*a*

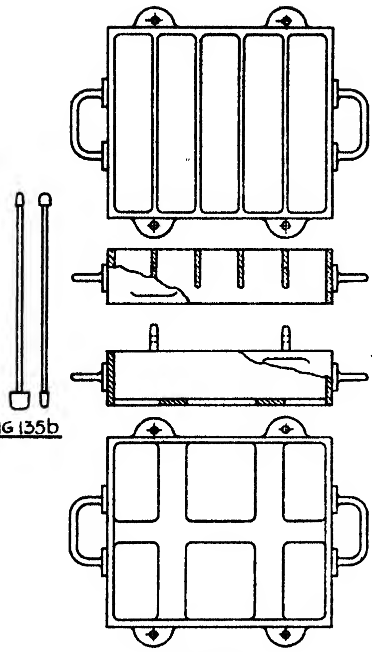


FIG 135b

FIG. 135a

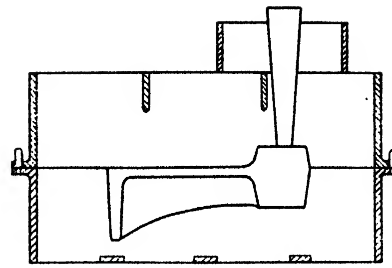


FIG. 136

shows typical top and bottom boxes, whilst fig. 136 shows a pattern in a mould.

A larger type of mould in a foundry floor is shown opposite. To prepare a mould such as fig. 136, an inverted top box is roughly filled with sand as a preliminary, and the small boss of the pattern pressed into it. An inverted bottom box is then placed over the pattern and fine sand, slightly moist, sieved over the surface to cover the

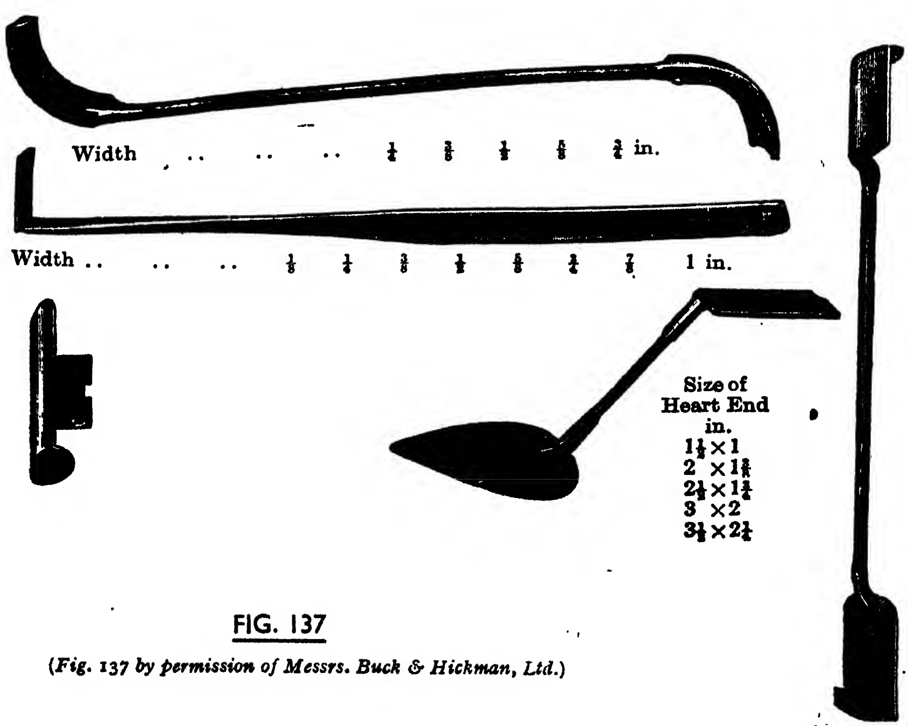
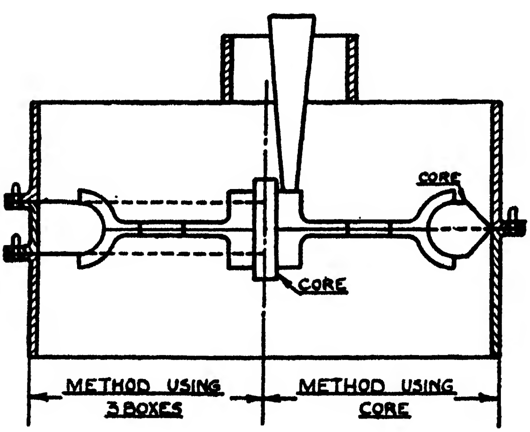


FIG. 137

(Fig. 137 by permission of Messrs. Buck & Hickman, Ltd.)

pattern. The sand is rammed firmly round the pattern and into the corners of the box with a rammer such as in fig. 135*b*. More sand is then rammed in, and finally coarser sand, to fill the box, each lot being rammed in firmly. This box is then removed and inverted to form the bottom box, and the surface smoothed over with the tools illustrated in fig. 137. A sprinkling of very fine parting sand is put over the surface and a top box carefully placed on to mate with the bottom box. The wedge shaped piece is held in position to provide a runway or "gate" for the metal, and sand is rammed into the box as before. Lines are marked on the boxes to ensure alignment on reassembling the mould for pouring. On removing the wedge, the top box may be lifted off carefully, leaving the pattern in the bottom box. After gently rapping, the pattern may be carefully lifted out of the mould; any pieces of sand which break away are dexterously replaced by the moulder.

The mould is then dried in an oven, and the boxes clamped together in alignment, as they were when the pattern was in the mould, and molten metal poured through the gate. Pressure is exerted throughout the molten metal by the molten column in the "gate"; this pressure helps to make the casting uniform in composition. For larger or more complex castings, extra columns, known as "risers," are added. The gates and risers also provide an outlet for any scum and allow for shrinkage cavities as the metal cools, without spoiling the casting. Extra risers also



ALTERNATIVE METHODS OF MOULDING WHEEL WITH HOLLOW RIM.

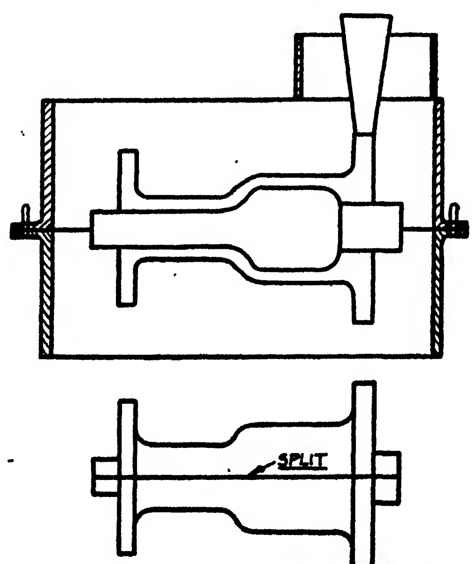


FIG. 138a

SPLIT PATTERN

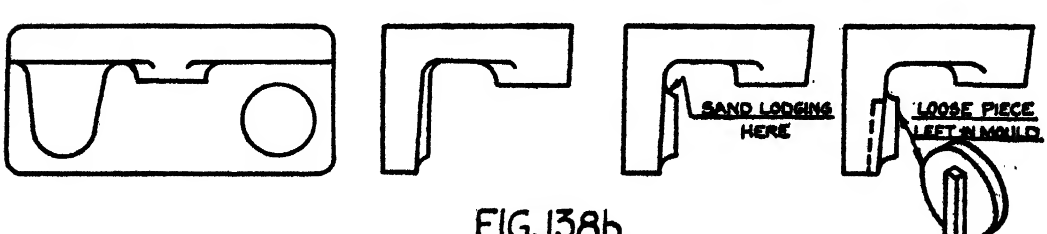


FIG. 138b

help to prevent the metal cooling and solidifying before reaching the extremities of a thin intricate mould. The moulder has to determine where gates and risers may be placed, and also to allow for air to escape from the mould, by making very small holes with wire, for vents.

Draft. The withdrawal of the pattern from the mould requires great care, but the operation is simplified if the pattern tapers slightly in the direction of withdrawal. The pattern maker must consider how the pattern will be placed in the mould when allowing this " draft."

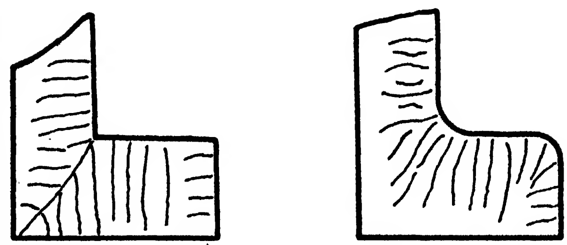
Coring is a very important part of moulding, by which the various holes and recesses in castings are made. The cores are made up from sand in special wooden core boxes, to the shape of the required space, and they are provided with extensions which support and locate them in the mould. The pattern, of course, has corresponding extensions known as " prints," to make a place in the mould for the core extensions (fig. 138*a*).

It is often convenient, especially in larger work, to split the moulds so that one half is in the top and the other in the bottom box, and the parts are then registered by dowel pins. Sometimes it is impossible to part (or split) a mould so that every projection may be withdrawn. In this case projecting parts are made loose so that, on withdrawal of the pattern, projecting bosses, etc., remain in the mould. They may then be drawn forward into the cavity. The use of such pieces should be avoided if possible, by modification of the design. The bracket (fig. 138*b*) illustrates the use and avoidance of drawbacks.

Severe stresses are caused in castings if large masses of metal are joined by thin sections, as the large masses remain molten after the thin sections have solidified. As the larger masses continue cooling and contracting, they pull severely on the thin sections. Sharp corners also are bad in a casting, for not only are they awkward to withdraw cleanly from the mould, but they promote a bad structure of the metal on solidifying (fig. 139). The designer therefore must join up thinner sections to bosses and thicker parts by generous fillets or curves, to smooth out the changes and ease the flow of metal. These points are illustrated by the castings shown in Chapter XII.

For certain metals it is inadvisable to bake the mould ; such moulds are called " green " sand moulds.

There are many other points in making of castings (*e.g.*, see fig. 208, page 160) which can only be gained by experience, but the student can learn much by examining castings and scheming a method of moulding and coring, and from examination of various patterns. Examine also the line round the casting which shows where the boxes met, the draft allowed, and the positions from which the gates and risers have been sawn, and consider the reasoning for such positions.



CORNERS OF CASTINGS
FIG. 139

MACHINE MOULDING

It must be remembered that for each casting a separate mould has to be prepared, which is broken up when the casting is withdrawn. The process is therefore comparatively long and costly when large numbers are required, but simple castings may be produced in large numbers by machine moulding, a much quicker process in which several patterns are secured to a plate which

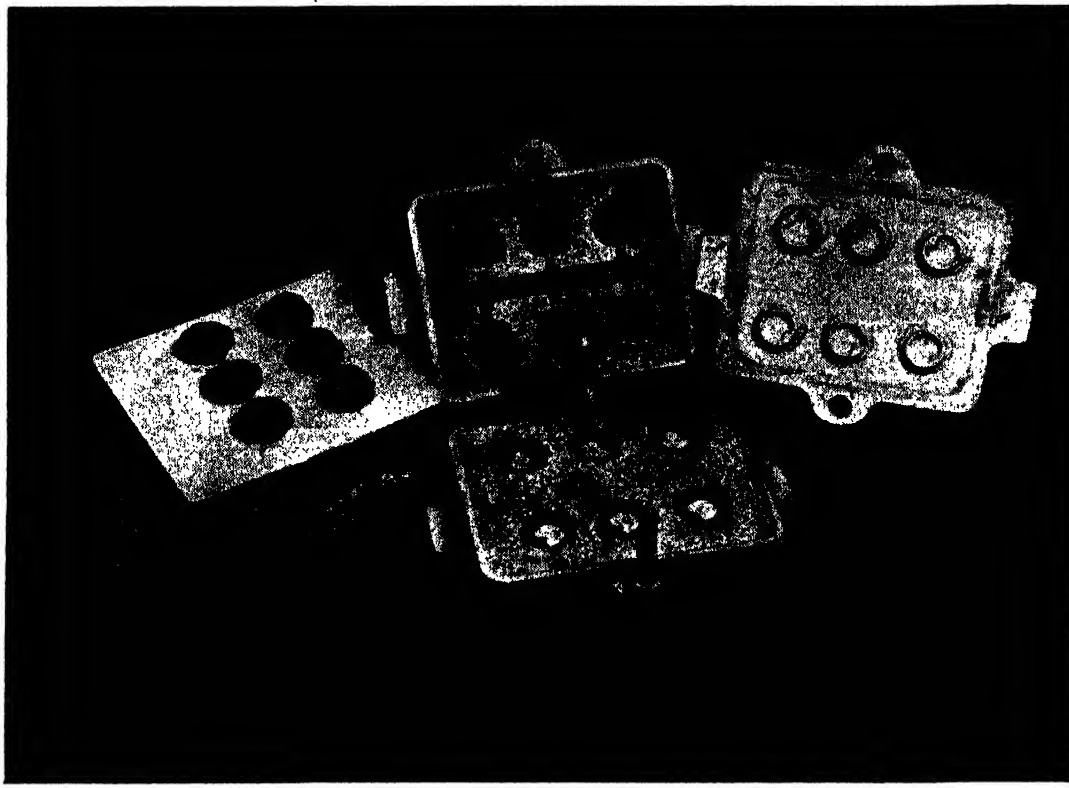


FIG. 140

(Fig. 140 by permission of Messrs. Kendall & Gent (1920) Ltd.)

is placed on the table of a machine, with a moulding box over it. Sand is then put in and rammed down by hydraulic or air pressure. The table is then jolted slightly by mechanical means to ease the pattern, and the box raised on a ram off the pattern. Patterns and moulds for such a process are shown in fig. 140.

DIE CASTINGS

Certain alloys having a comparatively low melting point, such as zinc, aluminium and magnesium alloys, and various brasses may be used for the production of die castings in which metal moulds and cores are used instead of sand. Great care has to be exercised in the design and finishing of these moulds, but when prepared, many hundreds of castings can be poured in the one mould. It is apparent, of course, that all cores and loose blocks must be withdrawn intact, whereas in a sand mould all are broken up. The molten metal may be poured in, or alternatively forced in under pressure. By either process great accuracy is obtainable, tolerances of two or three thousandths being permissible and sliding fits achieved, and in many cases machining operations eliminated, even threads being cast. A die casting mould with the component is shown in fig. 141.

FORGINGS

Forgings are made from steel or wrought iron by manipulating the metal

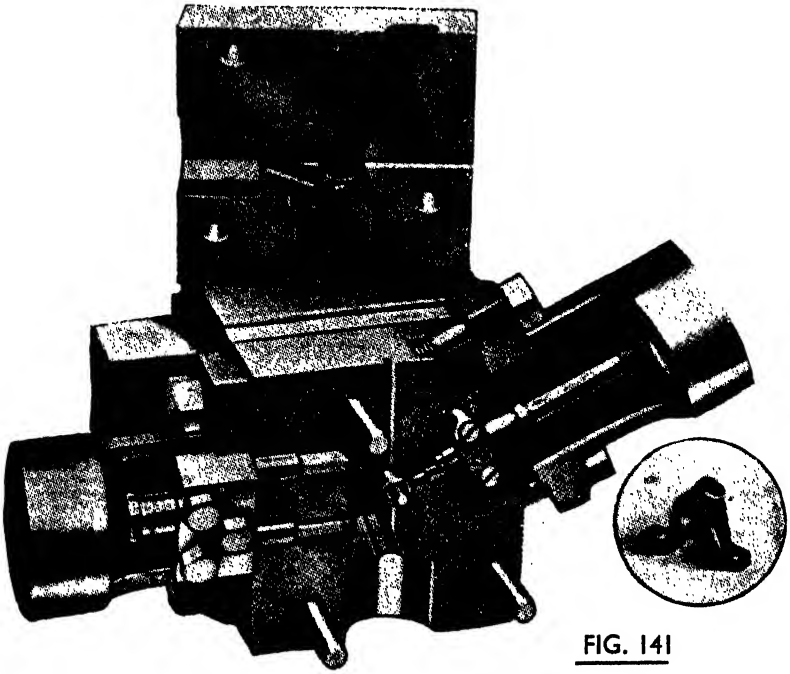


FIG. 141

(*Fig. 141 by permission of Messrs. H. B. Sale Ltd.*)

in its plastic state while red hot. Hand forging is a familiar process, and the blacksmith by skilful use of various tools such as swages and sets (fig. 142) can produce very complicated work. For heavy work, the steam hammer is employed with similar accessories. In the production of forgings the smith has to consider not only the final shape, but how the metal will flow most

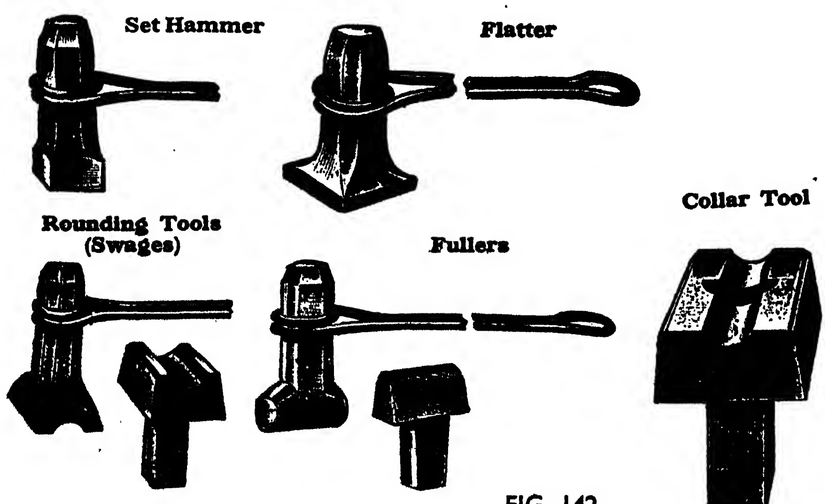


FIG. 142

(*Fig. 142 by permission of Messrs. Buck & Hickman Ltd.*)

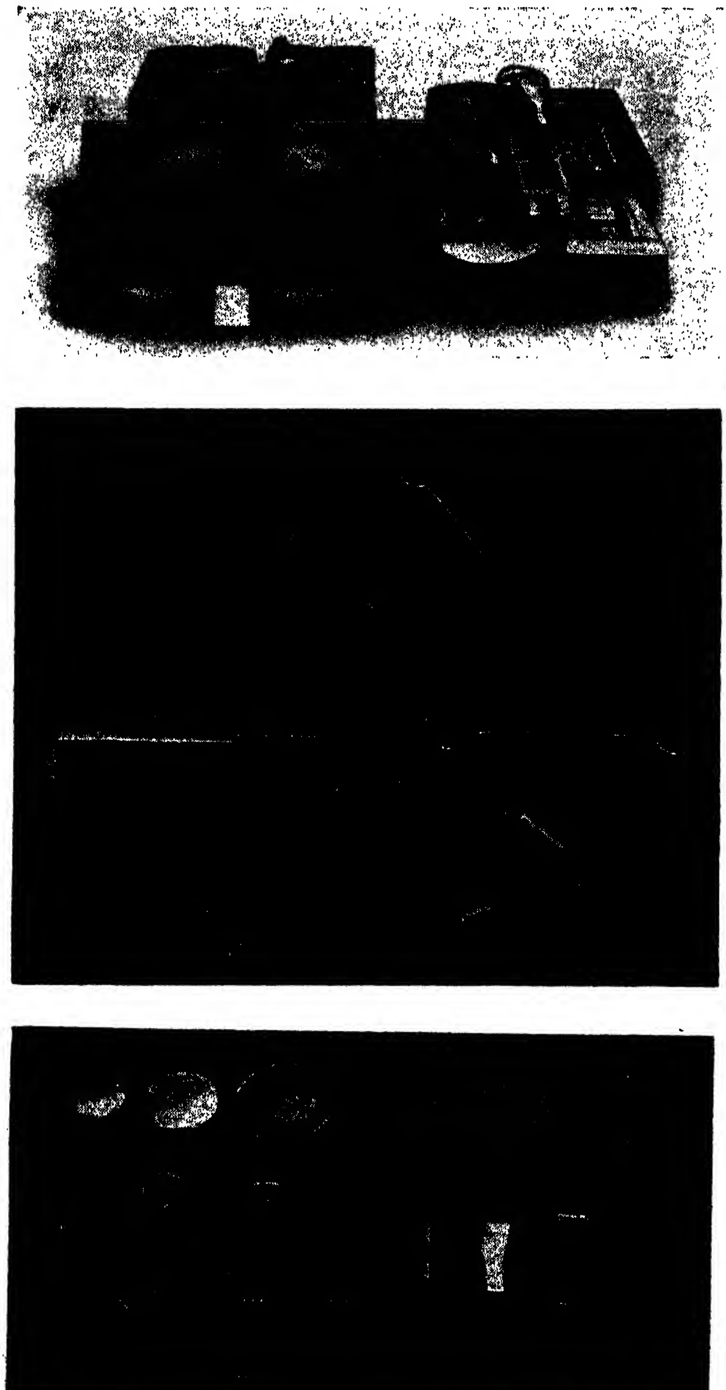


FIG. 143

(Fig. 143 by permission of Messrs. B. & H. Massey Ltd.)

favourably to the required shape without disturbing the metal structure.

When considerable quantities of forgings are required, a die block is prepared to produce **drop forgings** or stampings. The die is made in two parts, one firmly secured to the base of the machine and the other part to the upper moving member or tup. A previously prepared piece of metal is heated and placed in the lower die and the tup is then made to drop sharply to close the die. The sharp blow squeezes the plastic metal to the required shape. A collection of dies is shown in fig. 143 with a few typical drop forgings, while fig. 144 (frontispiece) shows the drop stamp and method of securing the die. The magnitude of the blow can be imagined when it is realised that in some instances the falling weight is as much as 11 tons, and the sharpness of the blow increases the force considerably.

Drop forgings are produced to such a precision that subsequent machining operations are very much simplified, since all the components are true to size and shape. After the stamping operations, the "flash," or thin edge of metal which squeezes through where the die

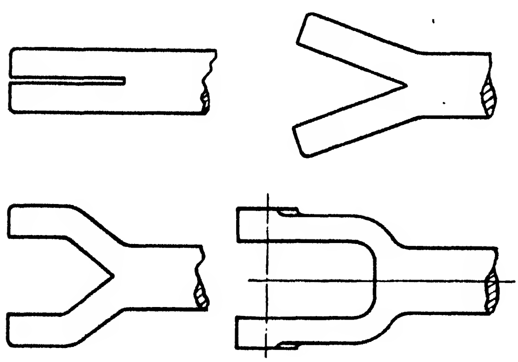


FIG. 145

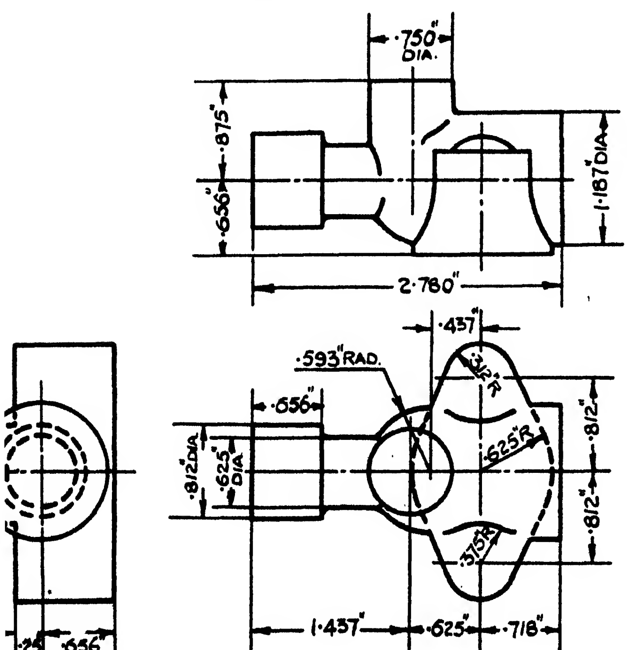
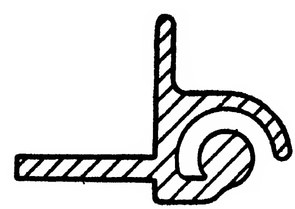


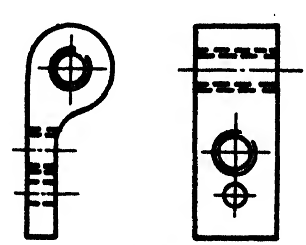
FIG. 146

SOLID BRASS STAMPING
VALVE BODY
(WEIGHT 16½ OZS (APPROX))



(a)

EXTRUDED BRASS SECTION
(FULL SIZE)



(b)

TERMINAL BLOCK
(EXTRUDED BRASS SECTION)

FIG. 147

(Figs. 146 and 147a by permission of Messrs. McKechnie Brothers Ltd.)

is parted, is removed. Not only steel, but various brass and aluminium alloys are suitable for stamping.

Machine forging is a very important process, in which the plastic material is squeezed by hydraulic pressure to form the shape. Fig. 145 shows the method used in producing a machine forged link by four stages. This method is important because the grain structure of forgings made in this way is so very satisfactory. Bolt heads and mushroom heads for internal combustion engine valves are formed on rods by this method.

Having considered the processes, it will be observed that forgings as well as castings should have a radius at all corners to avoid weakness, and drop forgings need a draft to facilitate their ejection from the dies.

Hot Pressing. A process allied to drop forging is that for the production of hot metal pressings, in which intricate shapes are formed by subjecting metal blanks to great pressure whilst in a plastic condition in a steel die. Various brasses and aluminium alloys are suitable for this purpose, giving a component having a good finish and a high degree of accuracy. A typical hot pressing is shown in fig. 146.

EXTRUSION is a process in which very plastic or molten metal is forced through a die to give a bar of accurate, and if necessary, intricate cross section. Small details are often conveniently made by slicing extruded bar into short lengths on a milling machine. An example of this practice is shown in fig. 147*b*. Brasses, copper and aluminium alloys are suitable for this purpose. An intricate extruded brass section is shown in fig. 147*a*.

WELDING

Welding is used very extensively as an efficient alternative to forging or casting. The process consists of joining two pieces of metal by fusing their junction, and a good welded joint is as strong as the original metal. Various steels, iron and aluminium alloys are weldable, though special precautions are necessary when welding two different types of steel, or steel to iron.

The heat for welding is produced with either an oxy-acetylene burner or by electrical means, and both methods have their peculiar advantages.

OXY-ACETYLENE WELDING

A jet of acetylene gas issuing from a small nozzle burns fiercely in a stream of oxygen, and plays on the junction of the two pieces to be welded. At the same time, a filler rod is held in the jet and in melting is deposited on the fused junction. The joints are carefully prepared, and the coating on the electrode acts as a flux to keep the joint clean.

The oxy-acetylene flame is also used, when reduced to a very fine jet, as an efficient means of cutting plate. Thickness of over one foot may be cut by the method, though the process is more usually applied to cutting irregular holes in plates of about 1 to 4 or 5 in. thickness.

ELECTRIC-RESISTANCE WELDING

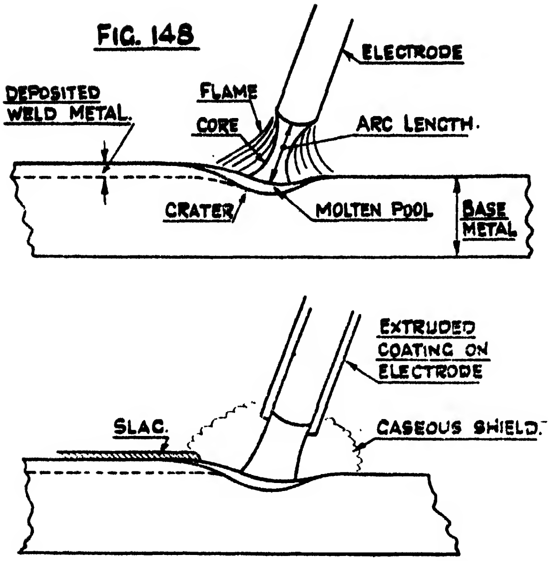
In this process the two parts are squeezed together and a heavy current passed through the two parts, the heat produced being sufficient to fuse the metal at the junction. There are three distinct types of resistance welding: (*a*) spot welding, (*b*) butt welding, (*c*) seam welding.

Spot welding consists of tacking plates by several short welds or spots. Since the heat applied is only local, distortion is more easily controlled, and, in fact, components are often spot welded first to avoid excessive distortion whilst continuing butt or seam welding.

Butt welding is the practice of butting components with pressure whilst passing the welding current.

Seam welding is similar to spot

FIG. 148



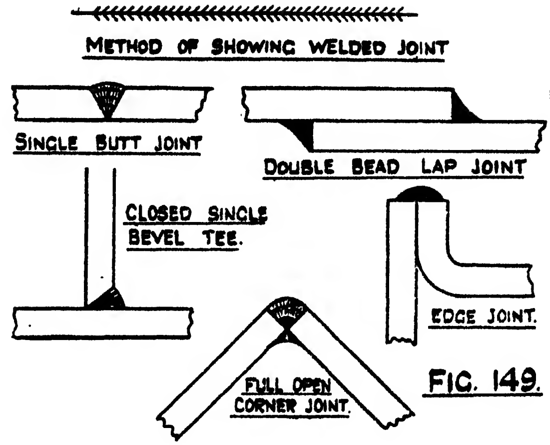


FIG. 149.

(*Figs.* 148 *and* 149 *by permission of Messrs. Lincoln Electric Co. Ltd.*)

welding, but a continuous weld is formed by using a rolling electrode.

ARC WELDING

The electric current is passed through an electrode to the work, jumping across a small gap. The spark or arc formed across the gap carries small globules of metal from the electrode which are deposited on the work surface. The heat is concentrated by the arc at the point of welding, where a small molten pool is formed and agitated, and the added metal is thereby thoroughly mixed.

ELECTRODES

In carbon arc welding, the electrode is a carbon rod, metal being added from a filler rod; lower current and voltages are necessary, but the total electrical consumption is greater by this process. The more usual electrode is a metal rod, of composition and size to suit the metal welded. In their passage across the arc, the molten globules of metal are exposed to the oxygen and nitrogen in the air, which is undesirable since steel has an affinity for these gases. Coated electrodes have a covering which, in the heat of the arc, gives off large quantities of inert gas which shields the arc completely; the coating also forms a slag which floats on top of the weld, protecting the molten metal whilst cooling. The slag is removed, when cold, by chipping or by wire brush. Fig. 148 shows the action of the electrodes and covering.

Preparation. It is usually necessary to prepare the joints as shown in fig. 149 to give place for the deposited weld metal, and a good welder works by depositing a layer of weld metal along a joint, then going over this with additional runs, each uniting to form the final joint. Skilful consideration in planning the runs is necessary to avoid distortion due to local heating of the parts.

To indicate a welded joint on a drawing, a line of short strokes, as in fig. 149, is the usual practice.[1] (See figs. 156 and 215.)

[1] See Chapter VI, fig. 89, page 73.

PRESSWORK

An important method of construction is the use of a press, on which sheet metal or certain other sheet material can be cut and bent to the required shape. Such pressings are often used either in conjunction with or as an alternative to, machined parts, castings or welded parts.

Pressings are produced by a press and a press tool. The press may be hand or power operated, the larger power presses exerting a force of 100 or more tons. The press tool is in two parts, one, usually the die, fixed to the press table, whilst the upper part, the punch, is fixed to the moving ram. The punch is forced into the die, and cuts or forms the metal between the two parts. The possible press operations are boundless, but the principal classifications are as follows :

(1) **Blanking,** to produce a flat-shaped component. A punch is made similar in shape (when looking at its end) to the required article, and a hole is cut in the die into which the punch just fits easily. When the material is placed on the die, the punch is pressed down and so cuts out the shape, pushing it into the die. The tool is designed so that the material is guided through and used without waste. One tool can produce several thousand identical components, one or more at every stroke of the press.

(2) **Piercing,** as the word implies, making a hole, either in a previously pressed blank or in a strip. Very intricate holes may be pierced, with very accurate location. Piercing is usually performed at the same time as another operation, such as blanking. For example a blank and pierce tool could be used for making washers.

(3) **Forming,** bending a blank into required shape, such as turning up lugs, etc. Tools for simple bends are often called bending dies.

(4) **Drawing,** forming a cup shape from a flat blank. The operation may be repeated several times, making the pressing smaller in diameter and longer at each stage. The operation hardens the metal, so that it often needs softening at certain stages. Cartridge cases are produced by this process, by stages as shown in fig. 150*a*.

(5) **Curling,** rolling a rim round the edge of a dish. Usually two or more stages are necessary for a complete roll over (fig. 150*b*).

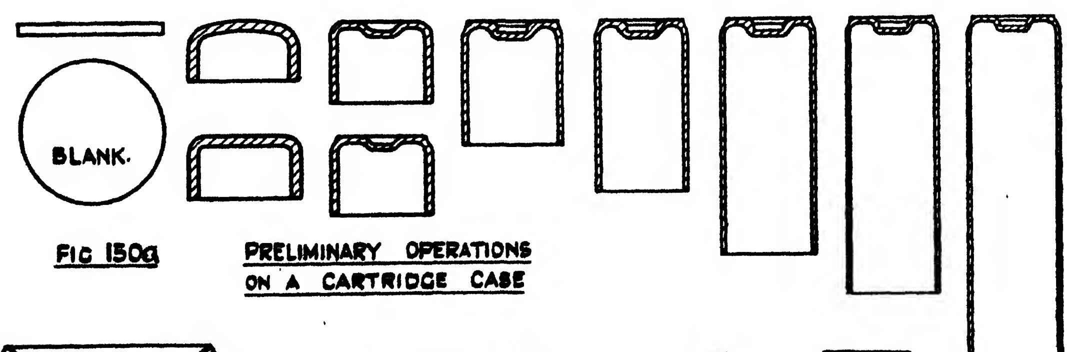


FIG 150a PRELIMINARY OPERATIONS ON A CARTRIDGE CASE

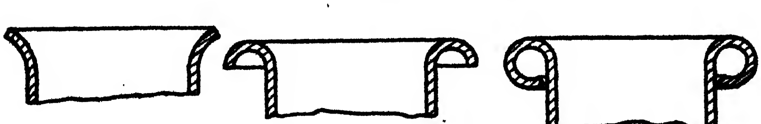


FIG 150b CURLING.

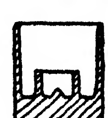
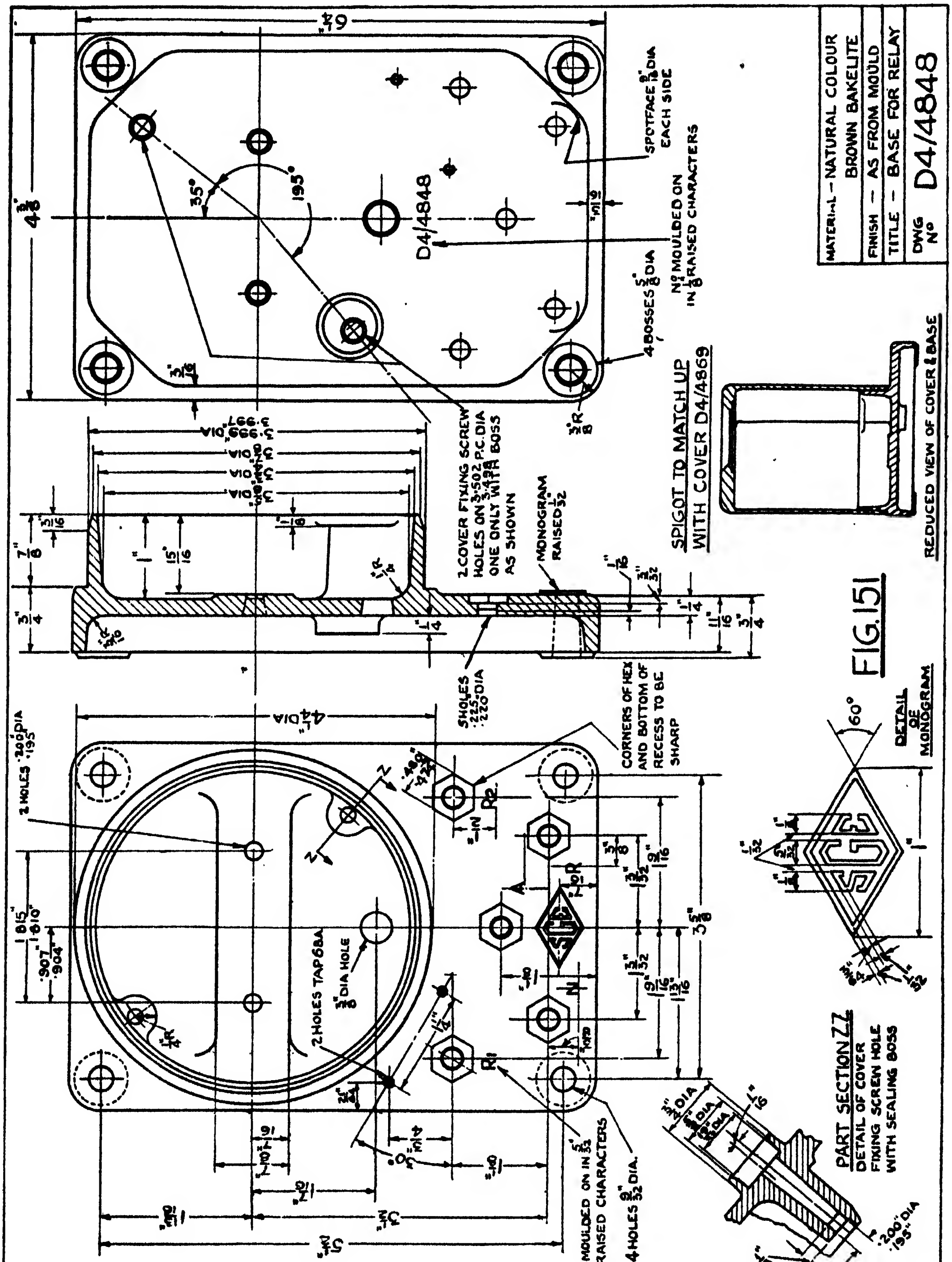


FIG 150c



(Fig. 151 by permission of Messrs. The Siemens & General Electric Railway Signal Co. Ltd.)

(6) **Shearing or cropping,** cutting off the end of a strip usually to some curved shape. Simple blanks may be made by cropping to the required shape on either side of the cropping punches (see fig. 165, page 130).

(7) **The extrusion process** (see page 114) has also been applied to press tools in which the metal flows under the pressure of the die to fill the die space. Fig. 150*c* shows a typical component from such a tool.

Dies may be made to perform several operations successively, such as a compound blank, pierce and drawing die to produce a perforated cup, or a follow-on die to pierce and blank a component. Fig. 91*d*, page 74, shows the die block for such a die producing washers, in which a continuous strip is pierced by the first punch, then passes on to allow the next punch to blank the first while the following component is pierced. Examples of press tools are given in Chapter XII, pages 130–133.

Pressings are made from sheet metal of varying thickness from a few thousandths to $\frac{1}{4}$ in. or $\frac{3}{8}$ in. plate, in steel, brass, copper, or aluminium alloys, and in paper and insulating materials.

PLASTICS

A comparatively new process is that for the production of components of varying complexity, by filling a shaped mould with a powder and applying heat and great pressure, forming the finished component. Bakelite, so called after the originator, Dr. Baekeland, consisting of a resinous powder with a colouring filler powder is the most common, though ebonite and shellac base powders have important properties.

Plastics are now made of great rigidity, and having the advantage of lightness coupled with ease of production and cheapness (when numbers are large), they have an important application in many industries.

The moulds are made from hard highly polished steel, with steel cores. As in die casting moulds, the component has to be removed without destroying the mould or cores, and in consequence great care is needed in designing tools for intricate work. By good design and workmanship, mouldings can be produced to a high degree of accuracy, within a thousandth per inch of length.

A moulded relay base is shown in fig. 151. Wherever possible, a more liberal draft is given than is usual on castings, but this may be reduced when essential, as on the 4 in. diameter which must fit the moulded cover. The holes are made by cores in the mould, and to avoid excess wear and sticking, the close limit on the hole is maintained only for a short length, then a taper is allowed—see part section ZZ. Notice also that whilst corners are rounded, sharp corners are possible where essential, as on the hexagonal terminal recesses. It should be noted that in mouldings it is easier to engrave the die, and so provide raised characters, than to emboss characters on the mould, for sunk figures on the moulding. Both the monogram and moulding numbers, therefore, are raised on the moulding shown.

THE DRAUGHTSMAN IN THE WORKSHOP

WORKSHOP REPAIRS AND MODIFICATIONS

It is often necessary to make a sketch of a component or a machine part actually in the workshop, as for example in the case of a breakdown or a modification to part of a machine. Such information, often gathered under difficult conditions, must of necessity be clear and complete. Many such examples are clear only to the draughtsman who made them, and to him for only a limited time. This, of course, is most unsatisfactory.

Though comparatively few engineers are artists, by considering the following points all can, with care, produce satisfactory freehand drawings. Do not refer to such drawings as freehand sketches ; a sketch suggests a shoddy, scrappy drawing. Think of them as freehand drawings, carefully prepared,

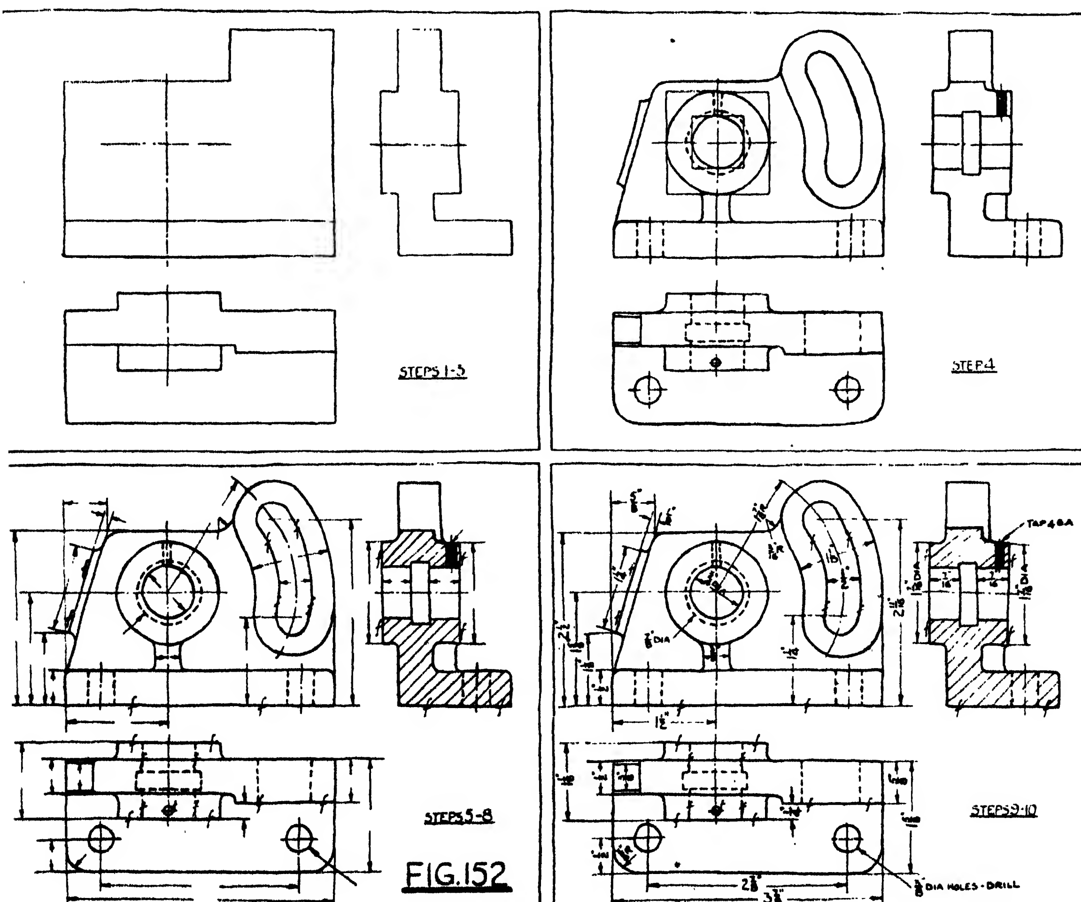


FIG. 152

proportionate and carefully dimensioned, differing only from a finished drawing in size and the fact that the lines are not drawn with rules or square.

Great practice is necessary in preparing a drawing from an actual detail, and skilled draughtsmen are liable to omit an essential dimension. It will be obvious that such an omission may be extremely expensive. The steps in making the freehand drawing are as follows. Resist the natural tendency to handle and measure up in the initial stages :

(1) Determine how many views are needed.
(2) Consider the proportions and divide sheet up into space for each view.
(3) Lightly outline a rectangle for each view and put in centre lines.
(4) Fill in the details of each view (as an aid to drawing circles, the circumscribing square may be inserted first).
(5) Insert machining marks.
(6) Put in limit lines and dimension lines where necessary, without putting in dimensions.
(7) Put in section lines.
(8) Consider if it is possible to make the detail with dimensions filled in where dimension lines are shown. (Be very careful with this check.)

Note. *Up to this stage there has been no need to handle the component, so that the drawing may be kept quite clean.*

(9) Measure up component and where dimension lines shown, insert figures.
(10) Check over completely.

In all freehand work, a softer pencil such as H or HB with a cone point should be used. Squared paper is useful to help in making the views in good proportion, and also to keep the views in correct projection. Because the work is freehand, there is no reason why the rules of projection should be ignored.

The bracket in fig. 152 has been drawn freehand by following the stages outlined above.

Chapter XII

INDUSTRIAL PRACTICE

THE MACHINE DRAWING IN INDUSTRY

Bonus vir semper tirem—a good man is always a learner.

" The learn'd reflect on what before they knew."—POPE, *" Essay on Criticism "* (1711).

HAVING studied the previous chapters, the student should be sufficiently familiar with machine drawing practice to be able to appreciate the important points

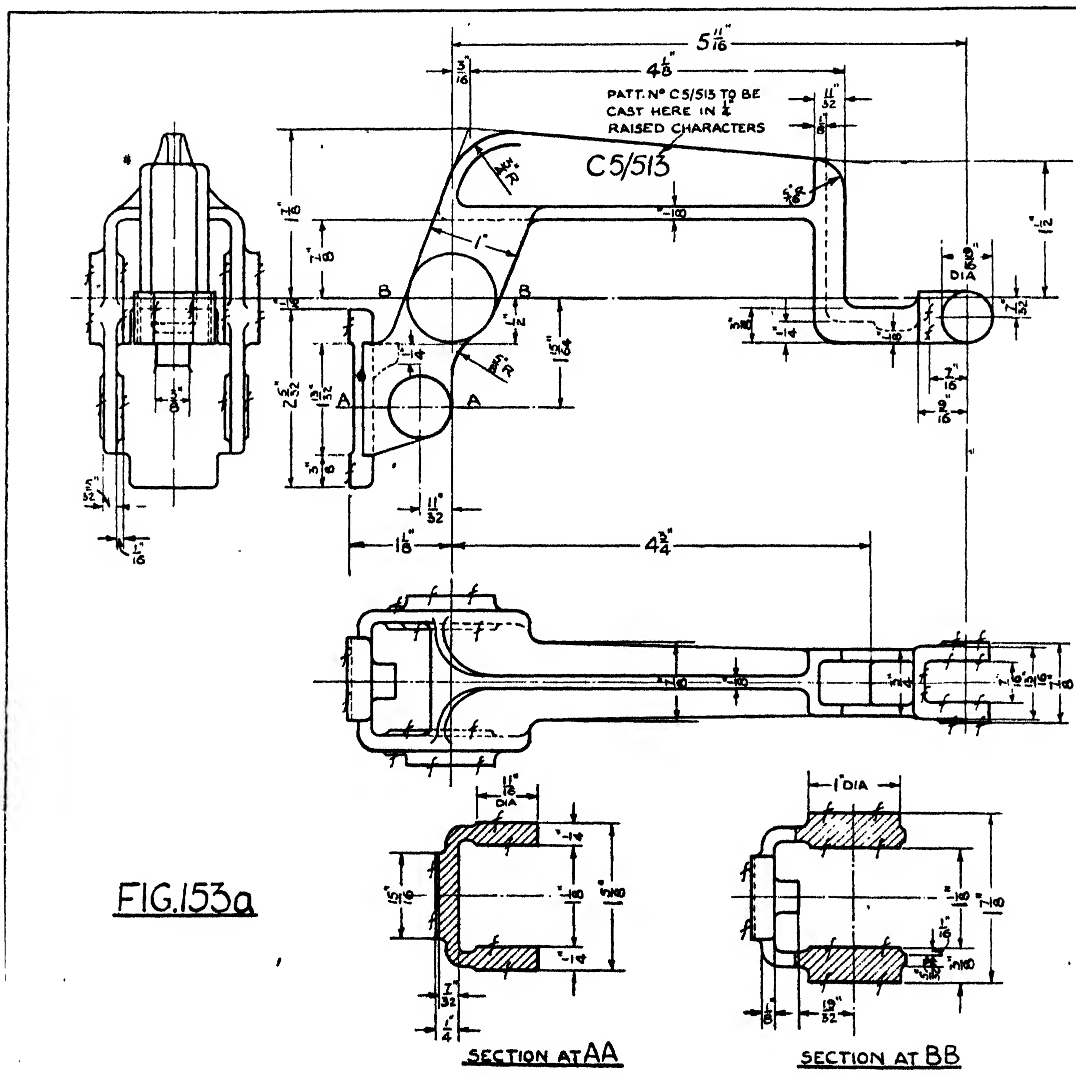


FIG.153a

(Fig. 153 by permission of Messrs. The Siemens & General Electric Railway Signal Co. Ltd.)

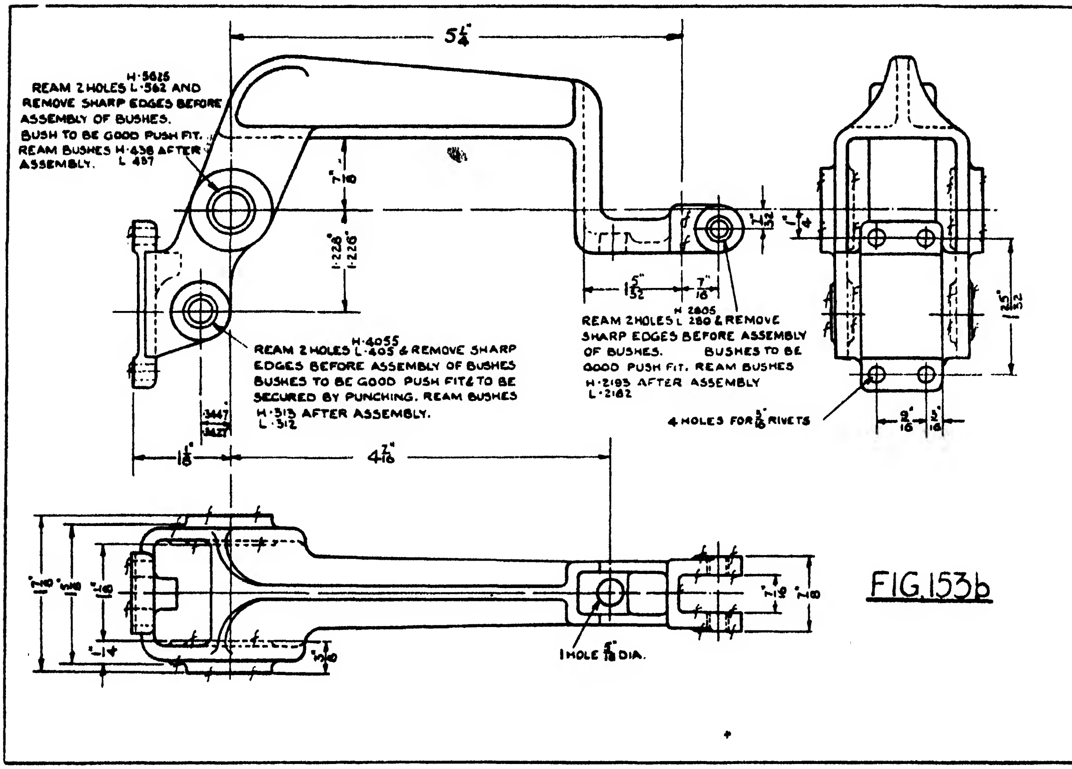


FIG.153b

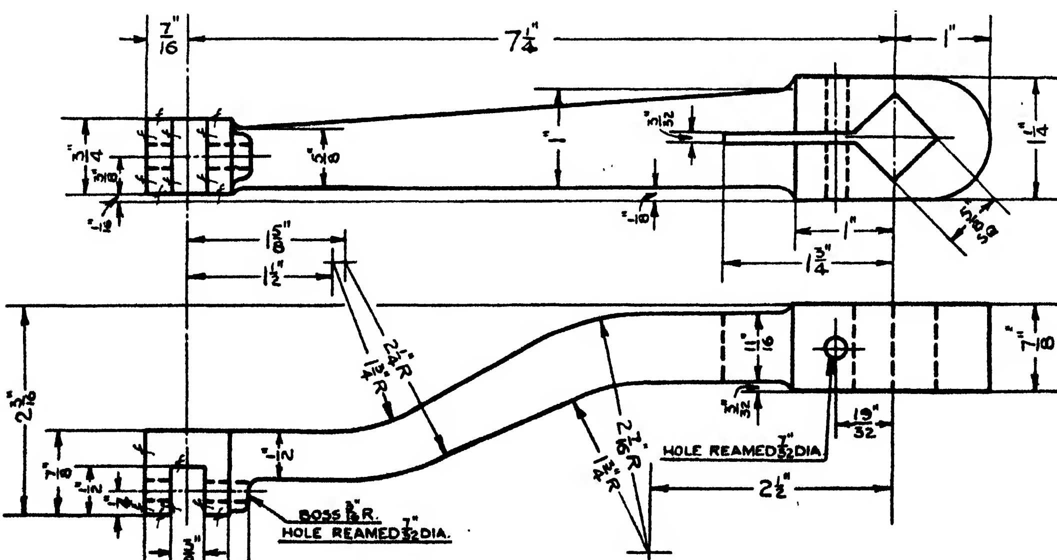


FIG.154 – KICK START LEVER
(NICKEL STEEL FORGING)

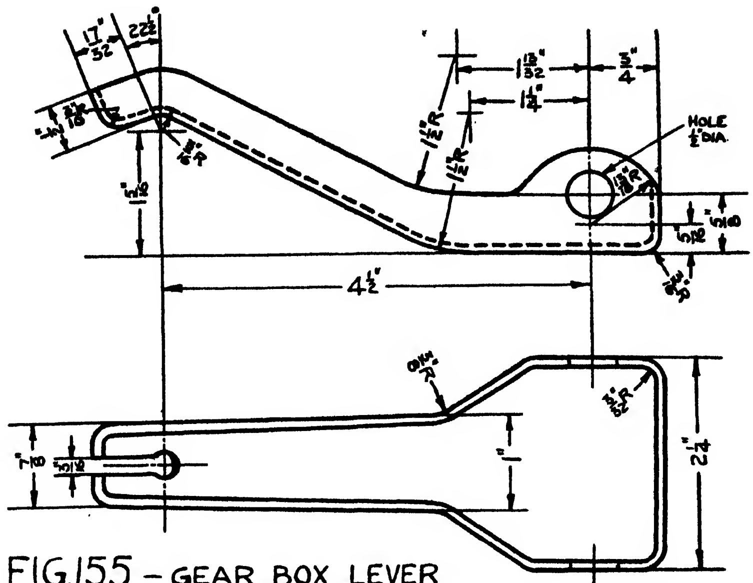


FIG. 155 – GEAR BOX LEVER
MATERIAL 13 B.G. (·092) M.S. PLATE

in a design both from the mechanical engineering and from the production engineering point of view. He should be capable either to produce a correct drawing of a component, knowing that the design is practicable, economical in production, of sufficient strength and pleasing in appearance, or to criticise a design constructively from these viewpoints.

In this final chapter, working drawings are discussed to illustrate the relative advantages of alternative methods of construction, and the effect of production method on the drawings used in various industries. A simple detail such as a wheel or lever may be manufactured in several ways, but according to the duty it is to perform, the material to be used and the numbers to be made, there is usually an advantage accruing to one method in particular.

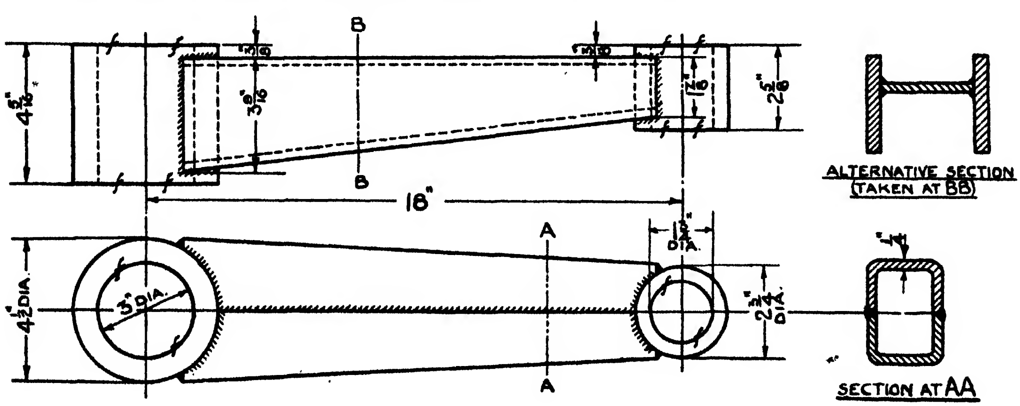


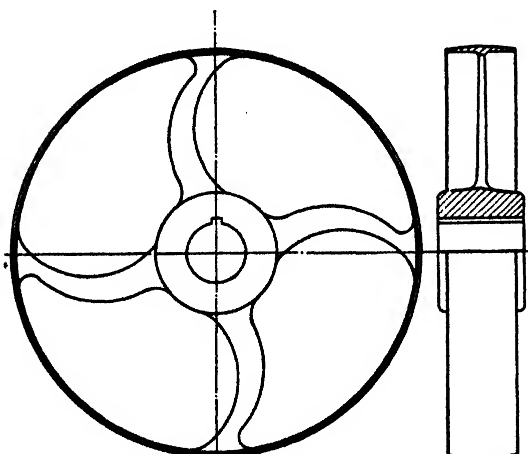
FIG. 156

(*Fig.* 156 *by permission of Messrs. Lincoln Electric Co. Ltd.*)

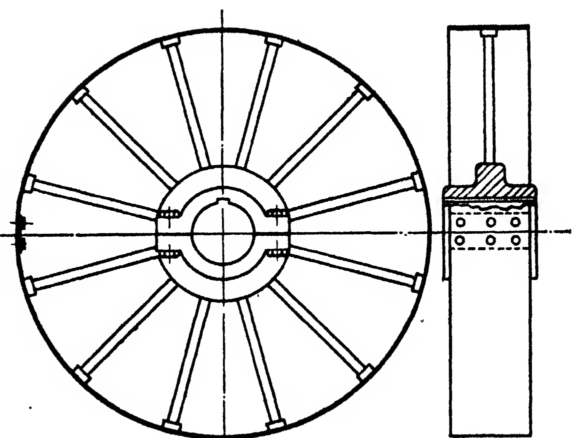
ALTERNATIVE CONSTRUCTION—LEVERS

(1) **Casting** (fig. 153). For lightness of movement, this lever for a railway signal controlling mechanism must be made of an aluminium alloy, and since the numbers required were comparatively small, it was cast. Had several thousands been anticipated it would have been more economical to die cast.

On the casting drawing (fig. 153*a*) all the dimensions required by the patternmaker are given. Where the lever is to be machined, extra metal is allowed on the casting (compare fig. 153*b*), but this extra allowance is usually left to the patternmaker, the dimensions being the same on each drawing. Notice the generous fillets in every corner, the ribbed channel or tee construction to increase the stiffness, and the method of numbering the casting. The use of a separate machining drawing is very satisfactory. Dimensions can be inserted



CAST PULLEY - FIG.158



BUILT-UP PULLEY - FIG.159

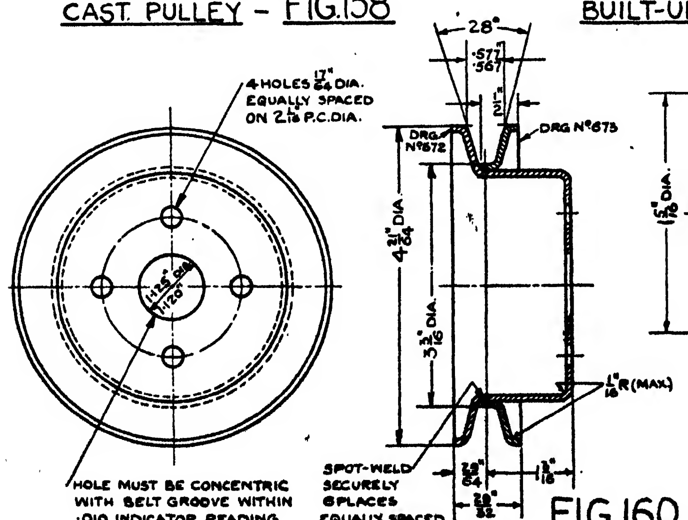


FIG.160

WATER PUMP AND FAN PULLEY - DRG No672 - 16 B.G.(0·062") MILD STEEL
PULLEY FLANGE - - - - - - - - - DRG No673 - 16 B.G.(0·062") MILD STEEL
FINISH - CELLULOSE SPRAY

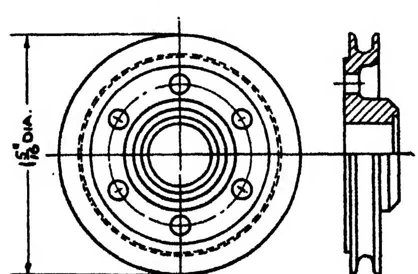


FIG.157

FIGS 157-160 - ALTERNATIVE PRODUCTION METHODS FOR WHEELS. (SEE ALSO FIG.169)

(*Fig.* 160 *by permission of Messrs. Vauxhall Motors Ltd.*)

with regard to their importance to the machinist, without the complication of casting dimensions. For example, the small boss is accurately located by the dimension 0·3447 in.–0·3427 in. ; to the patternmaker it is $\frac{11}{32}$ in.

(2) **Forging.** The kick-starting lever (fig. 154) is produced in large numbers, making the cost of a drop forging die worth while. It is stamped from nickel steel, a very tough material, which forges very well. Notice again the avoidance of all sharp corners, except on machined faces.

(3) **Pressing.** A motor cycle component (fig. 155) is produced in large numbers, permitting the use of press tools to blank and form the lever into a rigid box formation from steel sheet. No machining is necessary after leaving the presses.

(4) **Fabricating.** A lever from the operating mechanism of a power press of which only a small number were required is shown in fig. 156. The design is robust, and the welding, of course, as strong as the parent metal. The lever is built up from steel plates and bosses, shaped to suit before welding, and after fabrication machined as indicated. The finished lever is approximately half the weight of a comparable cast iron lever, and is produced without patterns or dies.

WHEELS

(1) **Machining.** Small wheels as fig. 157 may be turned from bar quite cheaply, either in large numbers by automatic or capstan lathes, or singly on a centre lathe. For larger wheels in quantity, the cost of waste metal must be considered, and drop forged or die cast blanks would be used, machined in the bore, and on the flange and faces.

(2) **Casting.** The cast iron pulley (fig. 158) is designed to minimise stresses due to contraction of the metal. The boss, even when cored out, is massive compared with the thin rim, which quickly cools and solidifies whilst the boss is still molten. Therefore, after the rim has assumed its final shape, the boss continues contracting ; the curved arms allow this contraction, whereas straight arms would undergo a severe tension. Observe also how the change of section is smoothed out by allowing generous fillets, curves and tapering sections.

(3) **Built Up.** To provide a lighter construction and avoid these cooling stresses, an alternative method of construction is to build up the wheel from steel plate and bars, with a cast or forged hub as shown in fig. 159.

(4) **Pressing.** Various sizes of wheel may be manufactured in large numbers by presswork ; if necessary, two discs may be welded to form a rigid construction. This method is used frequently in automobile practice, the thin plate stiffened by rib sections, giving lightness with great strength. Examples of this method are familiar in the pressed and welded construction of car wheels. Fig. 160 shows a neat, light assembly which, when secured to its hub, gives an effective drive, by means of a Vee belt.

JIGS AND FIXTURES

Reference has been made in the previous examples to the advantageous use of jigs and tools when several identical components are required.

A jig is designed to hold a component securely, and to accurately guide cutting tools whilst they perform a manufacturing operation on the component. A fixture is similar, but it only holds the work securely, it does not guide the tools. Since the fixture is positively clamped to a machine table, however, the tool is easily set from the fixture. The most common jig is the drilling or reaming jig, whilst fixtures are used largely for milling, grinding and turning operations. The possible arrangements of jigs or fixtures are endless. Even for one operation, several different jigs could be designed of varying simplicity, and the designer must judge between the cost of making the jig and the saving which it will effect. For a small number

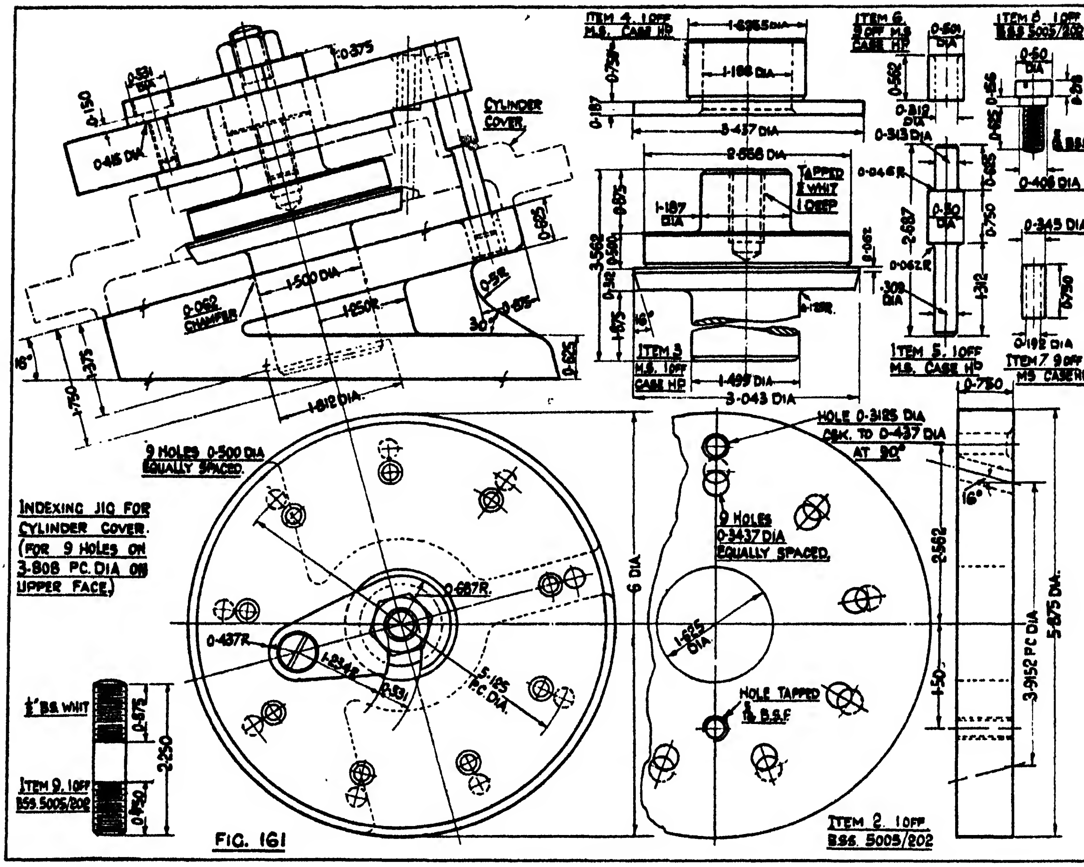


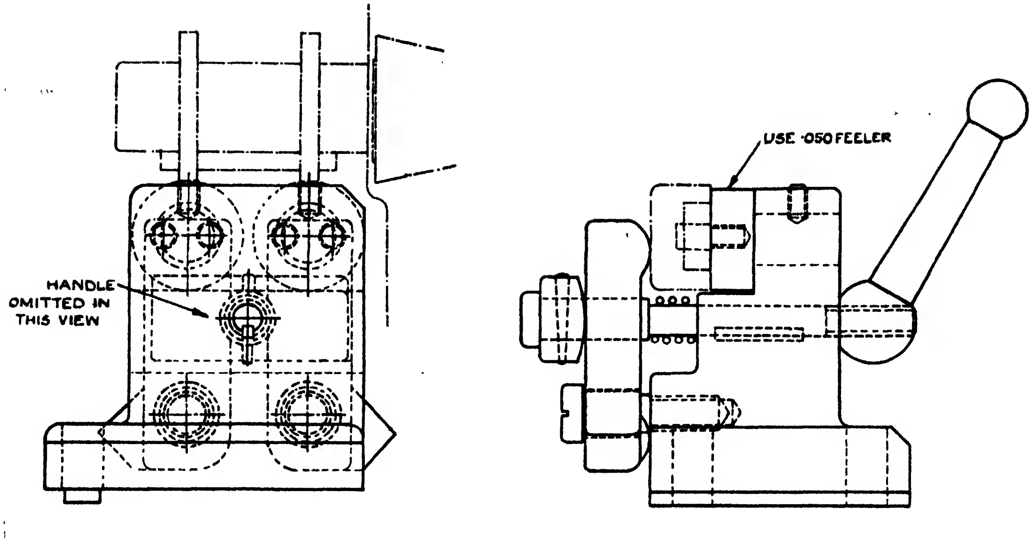
FIG. 161

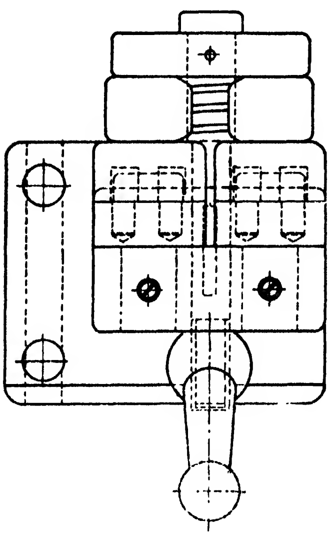
of components the simplest of jigs is needed, but for a larger number a more expensive jig, in which the component can be more rapidly machined, would be justified. A few examples of jigs and fixtures are shown. In jig and tool drawings, the work is not detailed separately, but several details are dimensioned, and notes are added calling for one part to fit into another. This is because each tool is made separately, and used as a unit, not as individual components which will need to fit any other mating component interchangeably.

In all jigs and fixtures the student should study the following points :

(1) How the job is located.
(2) How the job is clamped.
(3) How the work is supported against pressure of the cutter.
(4) How the swarf and cutting fluids may be cleared from the jig, leaving locating surfaces clear.

Example (i). Fig. 161 shows an indexing jig for drilling nine holes on a common pitch circle. Location is an important point in jig design. In this example the mandrel locates the work concentrically, whilst the inclination of the base provides for the converging axes of the holes. After loading the jig, that is, assembling the component between the cover and the mandrel, the pin is inserted into one of the indexing bushes, and a hole drilled. The unit is then lifted about $\frac{1}{4}$ in. so that the pin leaves the bush and is turned to allow the pin to drop into the next indexing bush, and so on for nine positions. After drilling, a slight turn of the nut per-





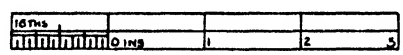


FIG. 162

(*Fig. 162 by permission of Messrs. Alfred Herbert Ltd.*)

mits the latch to swing back so that the cover can be lifted off passing over the nut ; the work is then taken off the mandrel. Consider the reason for the 16° bevel on the spigot and think how the dimension for the pitch circle on the cover was obtained. This is a comparatively simple jig ; if greater numbers of components were to be drilled it would be necessary to put a hardened steel bush in the base, or for still greater numbers it would probably be economical to make a more complicated jig which could be indexed more simply.

Example (ii). Fig. 162 shows a simple little milling fixture for milling slots in a safety cap. The components are located on the studs and the relationship between the slot and the semicircular grooves is determined by the ¼ in. diameter pegs. By means of the handle and screw the equalising clamp operates the clamps on both components simultaneously. When disengaged, the clamps swing out to a convenient position, resting on the lower projecting corners which prevent them falling right down. Note the use of the feather to prevent the screw rotating with the handle. A fixture does not guide the cutter, but provision can be made for setting it ; in this case, the flats milled on the pads are at a distance of 0·050 in. less than the dimension on components, so that

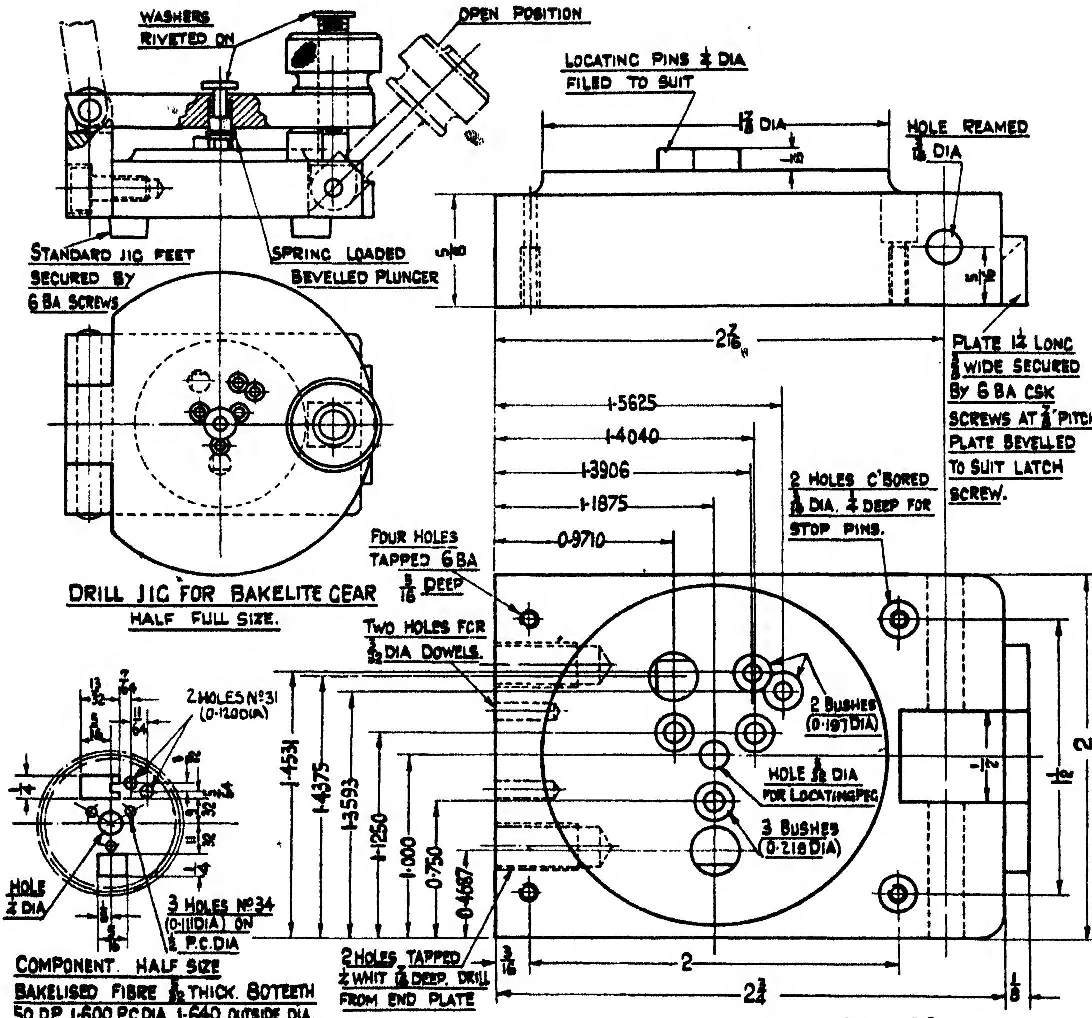


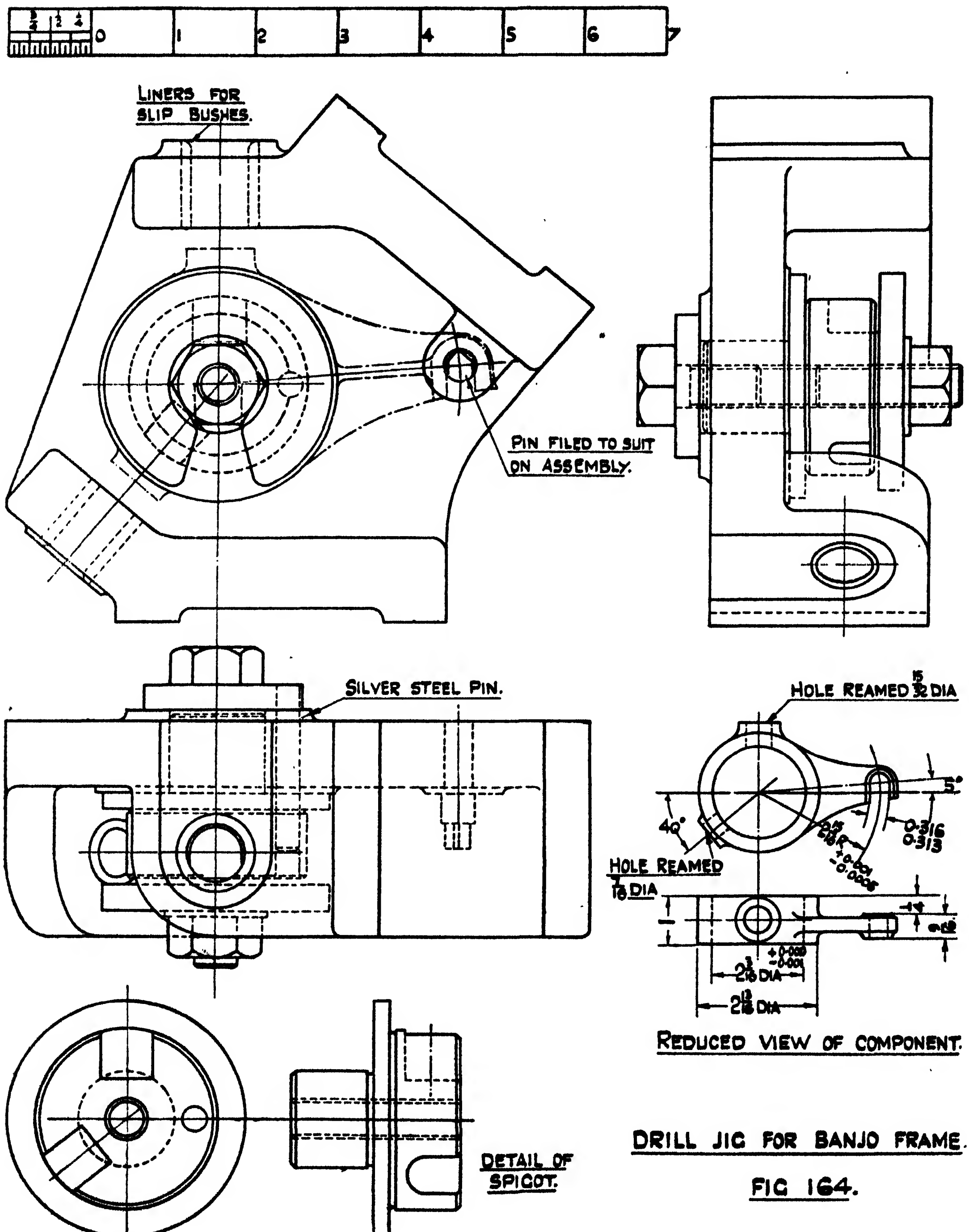
FIG. 163

the cutters are set by using a 0·050 in. feeler gauge on the pad. The fixture is bolted to the machine table by the holes in base, and registered in a parallel position by the tongue which fits the slots in the machine table.

Example (iii). A much smaller type for use on a two-spindle drill is shown in fig. 163. The machine spindles would have a No. 31 or a No. 34 drill, and the operator would pass the loaded jig from one to the other. The jig base is dimensioned to suit the tool room method of setting and boring. Note the use of standard parts such as the feet. Most tool offices have standard parts, such as knobs, latches, nuts, etc.

The component is dropped on the central locating pin, and the position determined by the filed-off pins. Since the blank was produced on a press, the uniformity allows precise locating. The cover is brought to a parallel position by resting on the two fixed pins, and the spring loaded plunger keeps the component flat on the base.

Example (iv). With the jig shown in fig. 164, two holes in the banjo frame



DRILL JIG FOR BANJO FRAME.

FIG 164.

are drilled and reamed at one setting. Location is taken off the slot, by means of the pin, and a turn of the nut allows the clamping washer to be removed and component passes over the stud and nut. After loading, the jig is stood on the two machined faces in turn to bring first one, then the other, hole under the drill spindle. Note the rigid structure of the cast iron body, designed to withstand the machining operation and the comparatively rough handling it may receive. Slip bushes are used for the drilling and reaming operations.

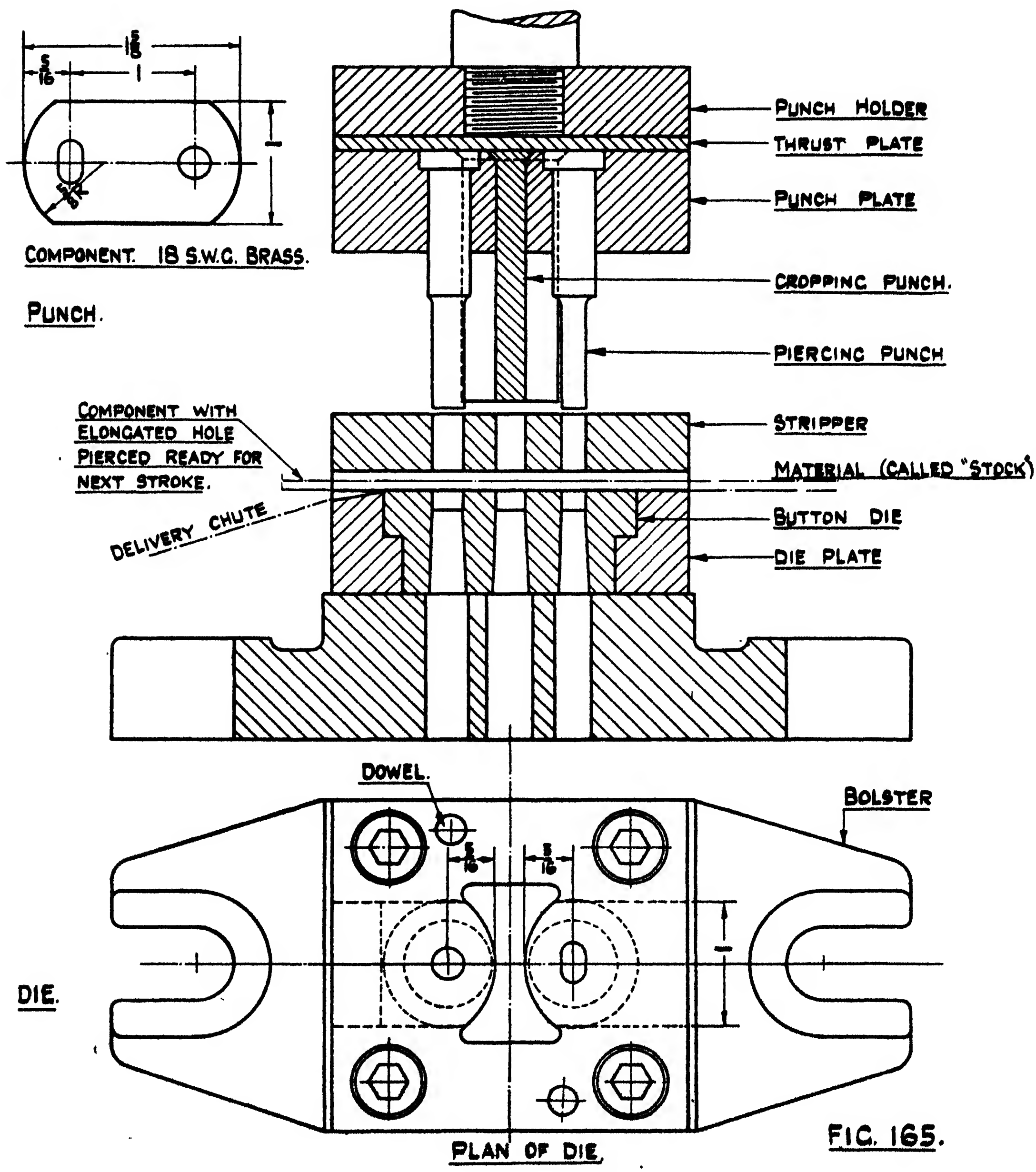
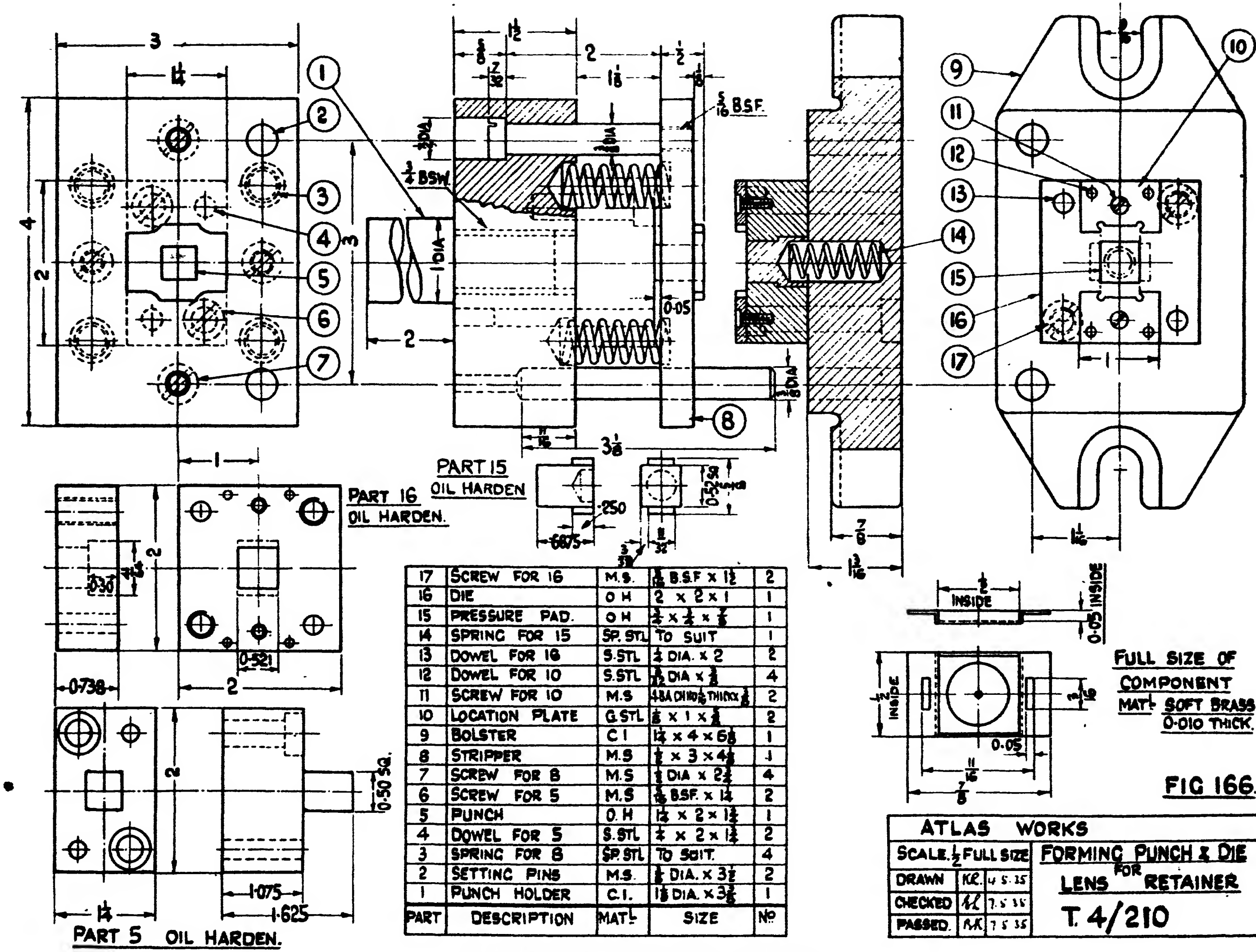


FIG. 165.



PART	DESCRIPTION	MAT^L	SIZE	No.
17	SCREW FOR 16	M.S.	$\frac{3}{16}$ B.S.F × $1\frac{1}{2}$	2
16	DIE	O.H	2 × 2 × 1	1
15	PRESSURE PAD.	O.H	$\frac{1}{2}$ × $\frac{1}{2}$ × $\frac{7}{8}$	1
14	SPRING FOR 15	SP. STL	TO SUIT	1
13	DOWEL FOR 16	S.STL	$\frac{1}{4}$ DIA. × 2	2
12	DOWEL FOR 10	S.STL	$\frac{1}{12}$ DIA × $\frac{3}{8}$	4
11	SCREW FOR 10	M.S	4BA CH HD $\frac{1}{16}$ THICK × $\frac{3}{8}$	2
10	LOCATION PLATE	G.STL	$\frac{1}{8}$ × 1 × $\frac{3}{4}$	2
9	BOLSTER	C.I	$1\frac{1}{4}$ × 4 × $6\frac{1}{8}$	1
8	STRIPPER	M.S	$\frac{1}{2}$ × 3 × $4\frac{1}{8}$	1
7	SCREW FOR 8	M.S	$\frac{1}{4}$ DIA × $2\frac{1}{4}$	4
6	SCREW FOR 5	M.S	$\frac{5}{16}$ B.S.F. × $1\frac{1}{4}$	2
5	PUNCH	O.H	$1\frac{1}{4}$ × 2 × $1\frac{1}{2}$	1
4	DOWEL FOR 5	S.STL	$\frac{1}{4}$ × 2 × $1\frac{1}{2}$	2
3	SPRING FOR 8	SP. STL	TO SUIT.	4
2	SETTING PINS	M.S.	$\frac{1}{2}$ DIA. × $3\frac{1}{2}$	2
1	PUNCH HOLDER	C.I.	$1\frac{1}{8}$ DIA. × $3\frac{1}{8}$	1

(*Fig.* 166 *by permission of Messrs. Kodak Ltd.*)

Observe the clearance allowed in the spigot to permit the tools and swarf to come through after the operation, and the design of the bosses to permit withdrawal of casting from the mould (see Chapter X).

PRESS TOOLS

The principal types of press tool were mentioned in Chapter X, and the following examples will help the student in examination of various pressings.

Example (i). Fig. 165 shows a progressive die, since one component is finished and the next component begun at each stroke. The material, or stock, is fed through the 1 in. slot up to the fixed stop, and after the first stroke the components drop out, usually being led off by a chute into a container. The small dies are of hardened tool steel, let into a mild steel die plate. Note the increased diameter of the piercing punches for strength, and the hardened plate over the punches to take the thrust. The stripper plate prevents the strip lifting up with the punches.

Example (ii). A forming tool is shown in fig. 166 in which a blanked shape is

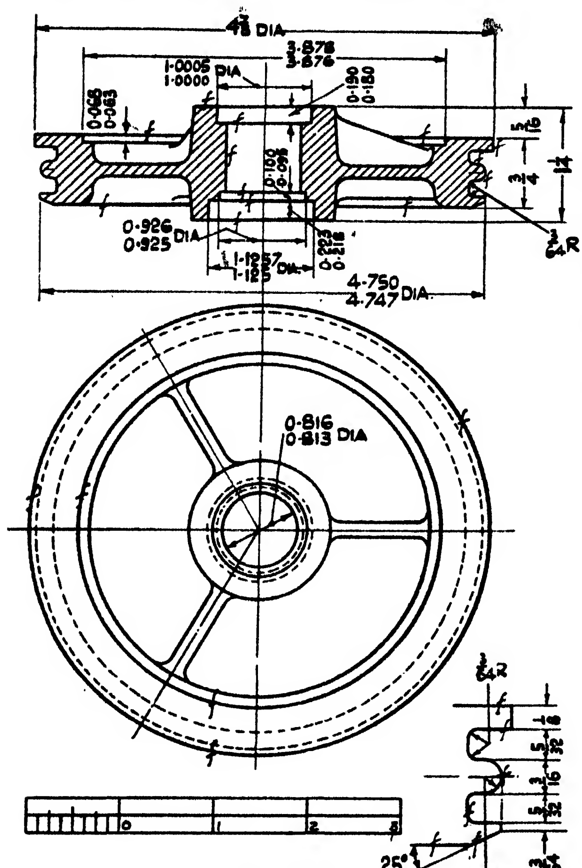
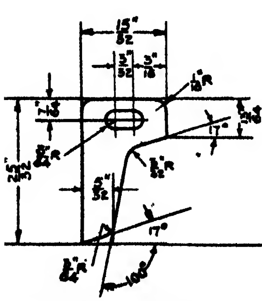
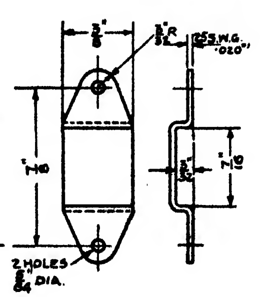


FIG. 167



BLANK FOR TERMINAL
BRASS 20 S.W.G. (·036)

FIG. 168a



KEY CLIP
PHOSPHOR BRONZE
(CENTRE DISTANCE BEFORE FORMING 1·050")

FIG. 168b

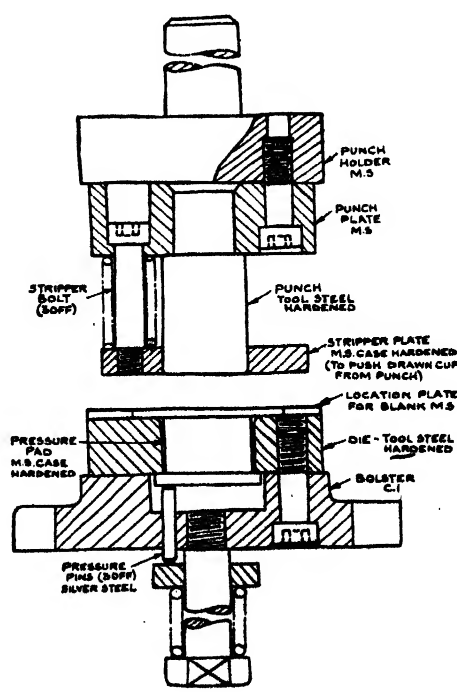


FIG. 169

gripped by the $\frac{1}{8}$ in. projection on the stripper against the pressure pad. The descending punch depresses the pad into the die and so forms the shape. The 0·05 in. dimension is controlled by the gap between the punch and stripper. The $\frac{3}{8}$ in. pins are for the purpose of setting the parts of the tool in line. Note that one fixing screw in a clear hole is sufficient for each location plate, since they are held in position by two $\frac{3}{32}$ in. dowels.

EXERCISE XIV

(1) In order to distribute the work in a factory it was decided to redesign the lever (fig. 155) as a drop forging with a cylindrical boss and an arm of Tee section. The shape must be maintained for clearing other parts. Make a drawing of the forging showing where machining is required, remembering that the die faces should if possible be flat. The $\frac{5}{16}$ in. slot is to be machined after forging.

(2) Fig. 167 shows the machining drawing of a wheel turned from a die casting. Prepare a casting drawing measuring with the given scale.

(3) The jig (fig. 161) is to be modified for a similar component, but having only six holes inclined at an angle of 15°. Draw a detail of the base suitable for such a modification.

(4) Detail the base and one of the clamps for the fixture (fig. 162).

(5) Show an elevation of the drill jig (fig. 163) in its unloaded or open position.

(6) Detail the jig body for the drill jig (fig. 164).

(7) A progressive pierce and blank tool is to be made for the component shown in fig. 168*a*. Layout the die block in an economical manner, allowing about $\frac{1}{32}$ in. between successive components. ($\frac{5}{16}$ in. strip—21 components per foot length. Note: lay out the blanks first.) (See fig. 91*d*.)

(8) Detail a die block with location plates for forming the component shown in fig. 168*b*.

(9) A disc of 18 S.W.G. (0·048 in.) brass strip, $2\frac{1}{4}$ in. diameter is to be drawn to a cup $1\frac{3}{8}$ in. inside diameter. Fig. 169 shows a rough scheme for the tool. Design the die for this operation, allowing 0·003 in. clearance between the punch and die. (Assume depth of cup is $\frac{5}{8}$ in.)

STEAM ENGINE AND AUTOMOBILE DETAILS

It has been stated that the decision concerning the use of tools as described depends upon the number of any particular component to be produced. The two types of production are exemplified in a general way by the following engine details, since marine steam engines are usually made in small numbers, whereas the automobile engine is produced by large-scale methods. The design of corresponding engine parts also varies very largely in each type of engine on account of the different conditions.

A skeleton diagram of a steam engine mechanism is compared with that for an internal combustion engine in fig. 170, and the relationship of the various parts indicated.

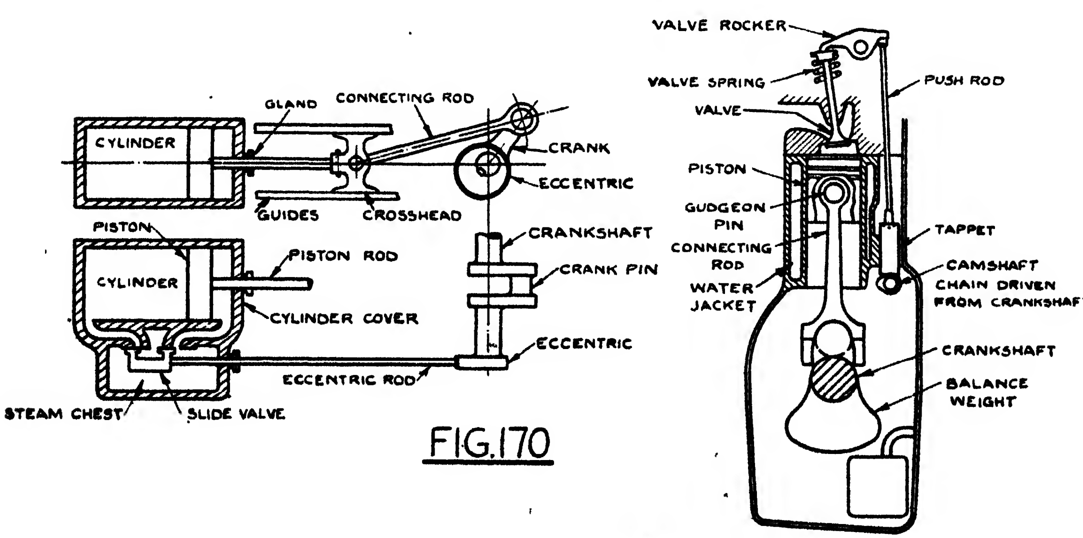


FIG. 170

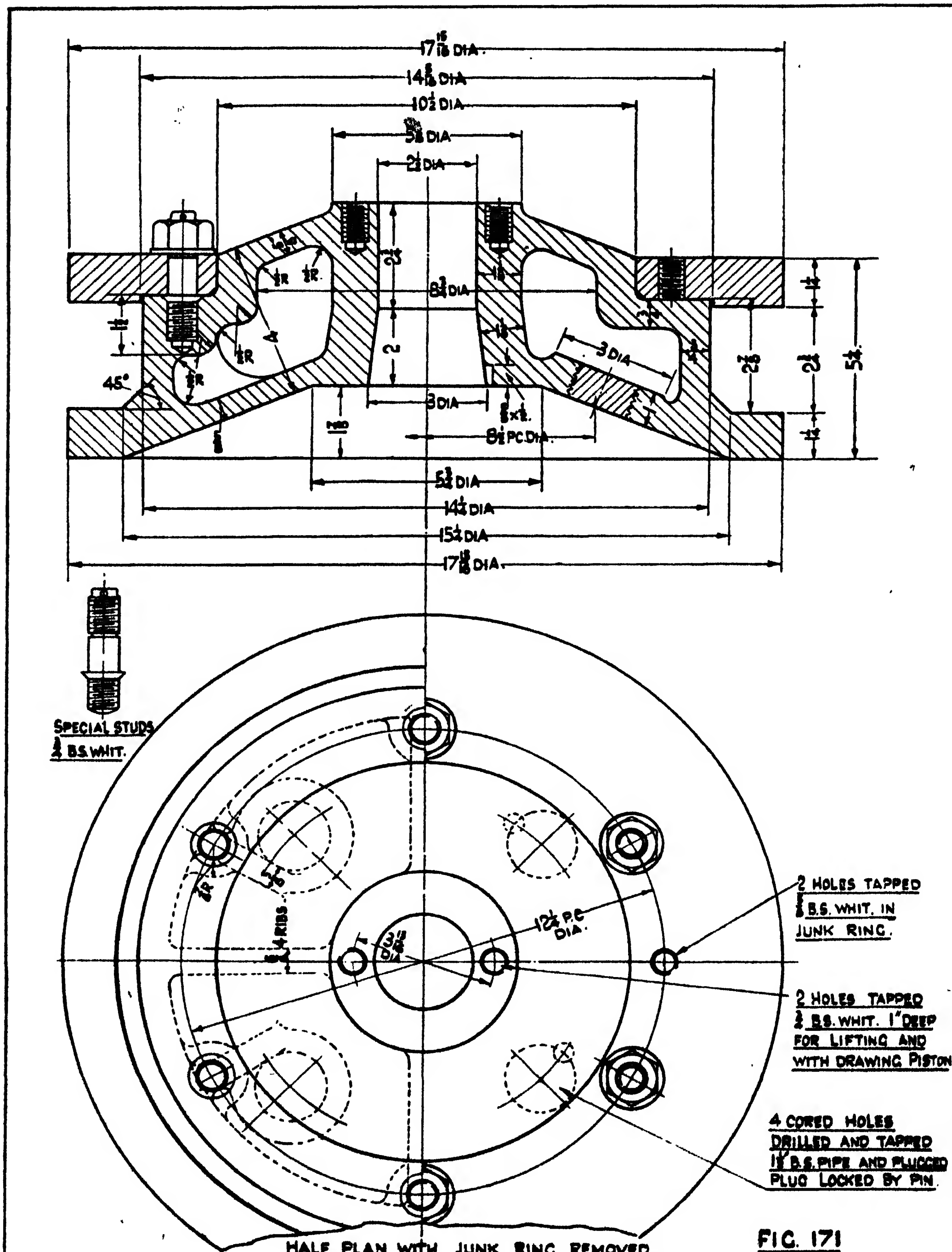
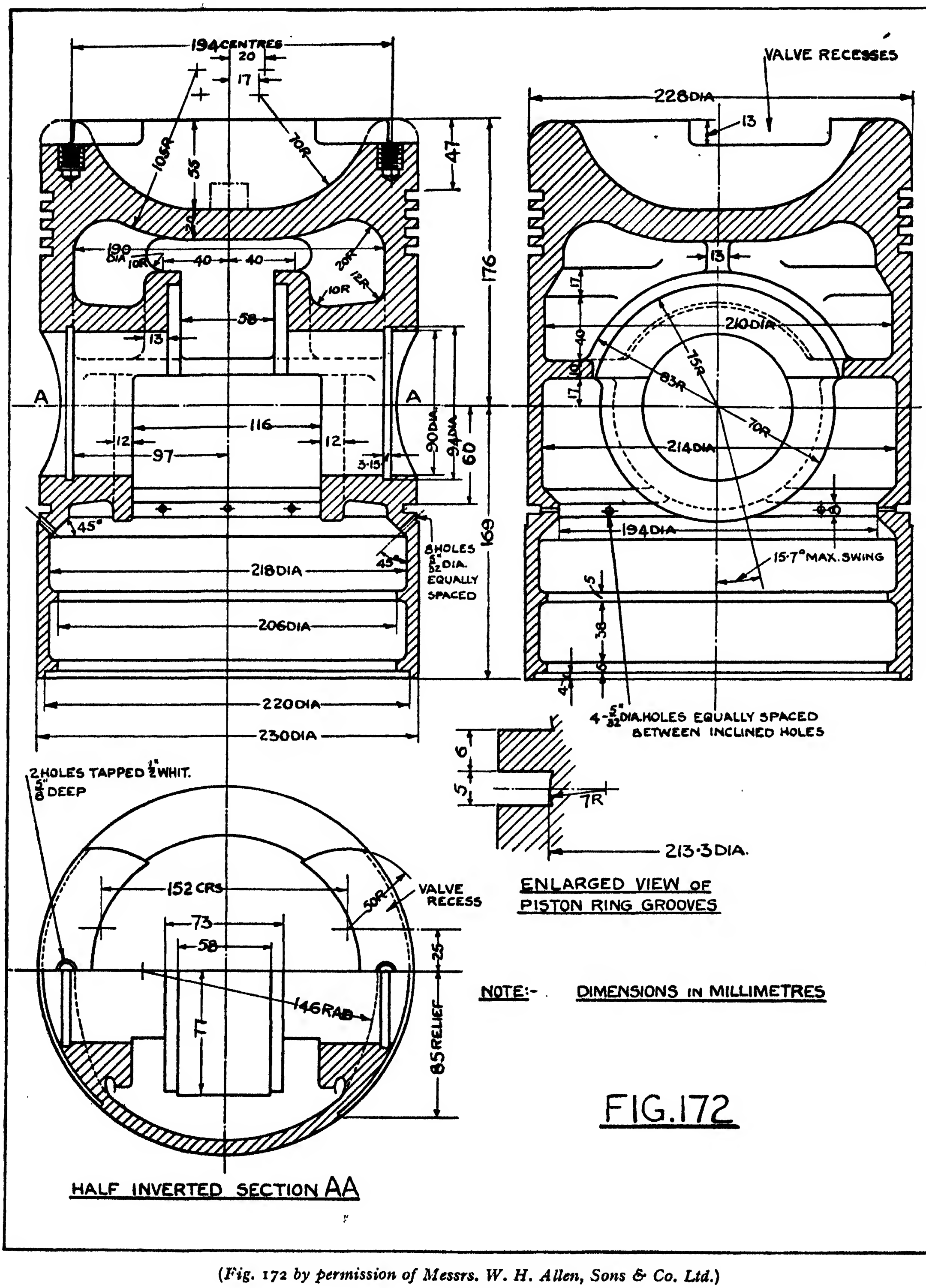


FIG. 171

(Fig. 171 by permission of Messrs. J. Samuel White & Co. Ltd.)



(*Fig.* 172 *by permission of Messrs. W. H. Allen, Sons & Co. Ltd.*)

PISTONS

The steam engine piston is secured to the piston rod which is constrained by the movement of the cross head in the guides, but the I.C. engine piston is longer in proportion, so that it will keep in alignment. Owing to the much higher speeds in general use in the I.C. engine, the pistons are of lighter construction, and many other factors influence the design of an I.C. engine piston, such as the localised high temperature, but these must be left for later consideration.

Figs. 171–2 show pistons for marine engines, steam and diesel respectively. The cast iron piston of fig. 171 is cored for lightness, the core being supported through the four holes which are subsequently tapped and plugged. The plugs are then locked with pins to prevent rotation. The junk ring secures the piston ring which is of the type illustrated in fig. 173, the name "junk ring" being a survival of the days when piston packing was less scientific than at present. Notice the unorthodox sectional view for the right-hand half of the elevation, in which the tapped core hole has been moved round to the section plane at the centre line, and also the similar case showing the stud and rib in the left-hand half. This practice is common in such work as marine engines, where small numbers of parts are made from the one drawing.

The construction of the cast iron diesel engine piston (fig. 172) is entirely different; the domed top is shaped to improve the combustion which takes place above the piston head. Notice the boss, cast on the top face for convenience in machining only; it is removed at an early stage. One of the earliest operations on the piston is the boring of the recess at the bottom; this again is only done for convenience in machining, the recess being used for locating the piston on a spigot, whilst a centre is brought up to the boss in the head. The piston is designed for lightness and strength, particularly at the crown where severe forces are experienced. Note the heavy ribbing there and the lighter ribbing at the skirt. Four sprung cast iron piston rings are fitted, ground very accurately to thickness to prevent the gases, at very high pressure, leaking past.

Piston Rings. A ring suitable for a steam engine piston is shown in fig. 173. It consists of two hard, close grain, split cast iron rings with a coiled spring, which is compressed in the groove. The spring exerts a force tending to separate each ring, and also an outward force pushing the rings against the cylinder walls. The forces exerted by the spring are controlled by its length, which is adjusted where necessary by screwing one end into the other. There are various other types of ring for special purposes.

Piston rings for I.C. engines are made of cast iron, the simple type being turned from a "pot" which is cast in a mould rotated at high speed whilst the metal is solidifying, to give a hard, close grained iron. After boring and turning, the rings are cut off accurately to width, then split diagonally (fig. 174).

In order to achieve uniform pressure all round the cylinder wall and to ensure good fitting in the grooves, several satisfactory patent type rings are marketed.

CONNECTING RODS

The stresses involved in the connecting rod of a high speed I.C. engine are different from those in a rod for a slow steam engine, for the higher speeds induce forces which fluctuate rapidly, and also tend to bend the rod. It is especially desirable to make such a rod capable of withstanding these varying forces whilst being as light as possible.

Several interesting features are shown in fig. 175, the connecting rod for the same engine as the piston in fig. 171. Particulars of each detail are shown on the one drawing, the usual practice in

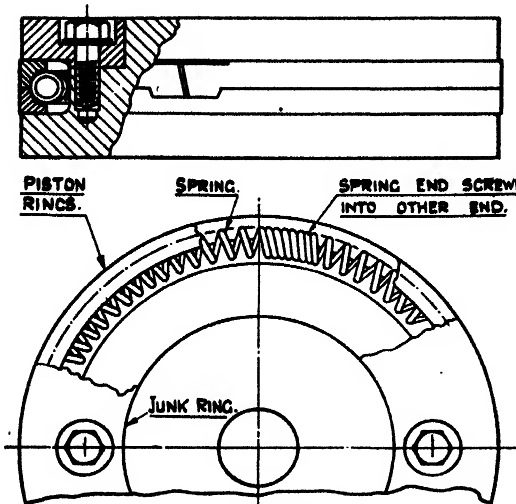


FIG. 173.

(*Fig.* 173 *by permission of Messrs. Lancaster & Tonge Ltd.*)

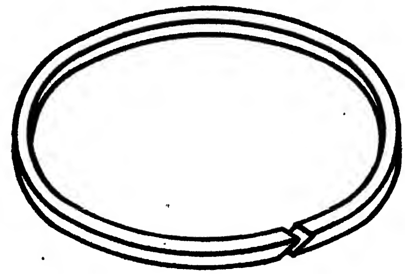


FIG. 174

the workshop where engines are made individually, the details being made to suit, not to "limits" as in other examples. The gunmetal "brasses" are bolted, with the steel keep and brass liner, to the forged steel rod by the special mild steel bolts. Dovetail recesses are cast

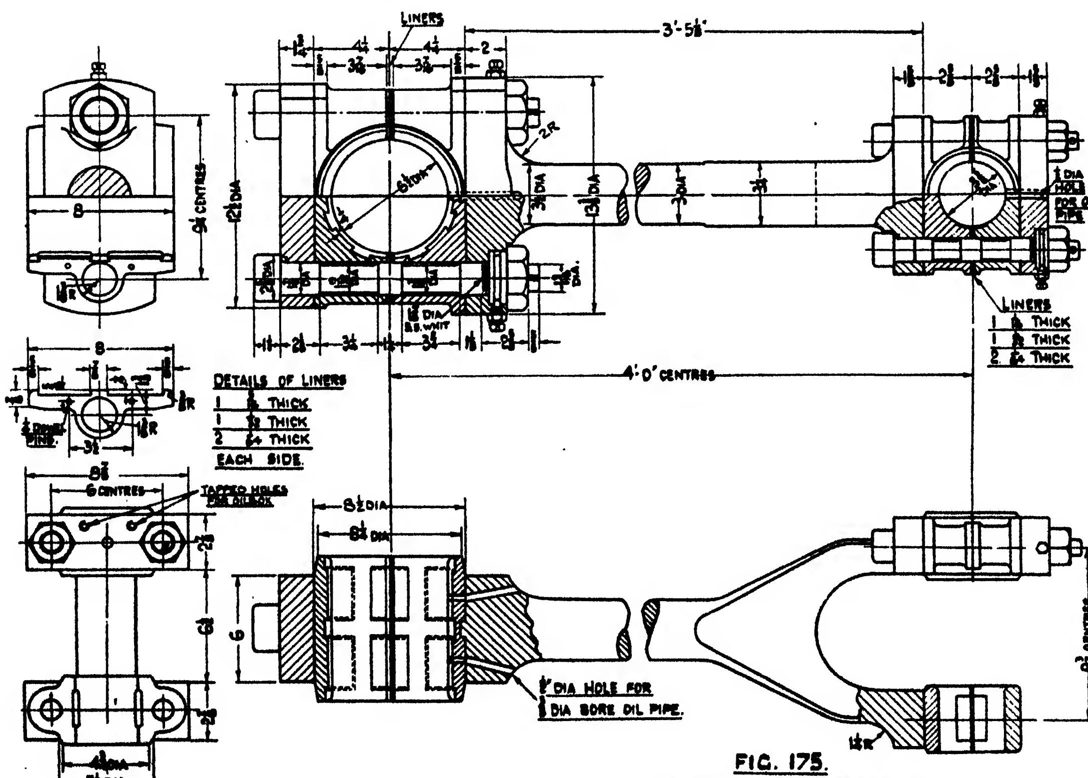
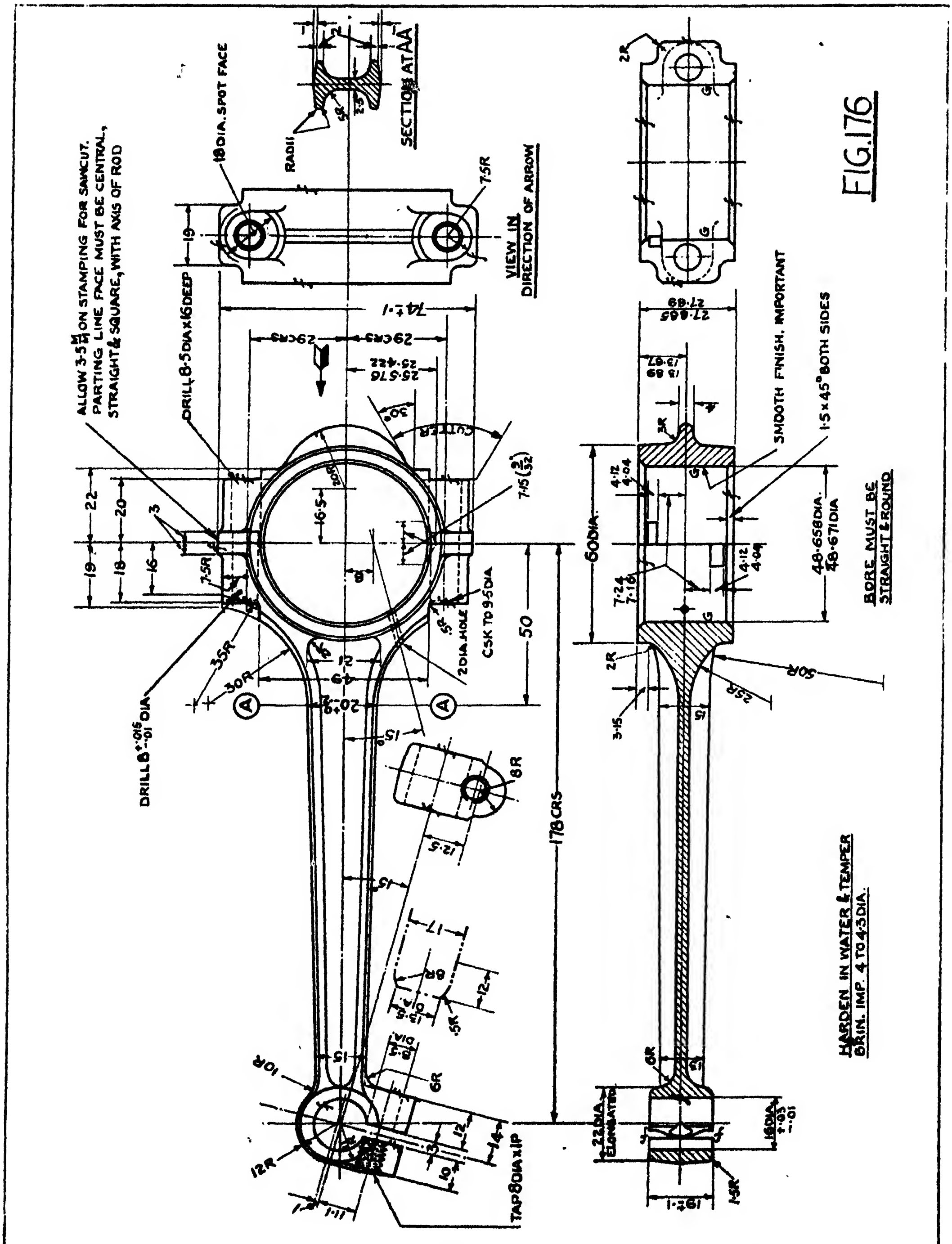


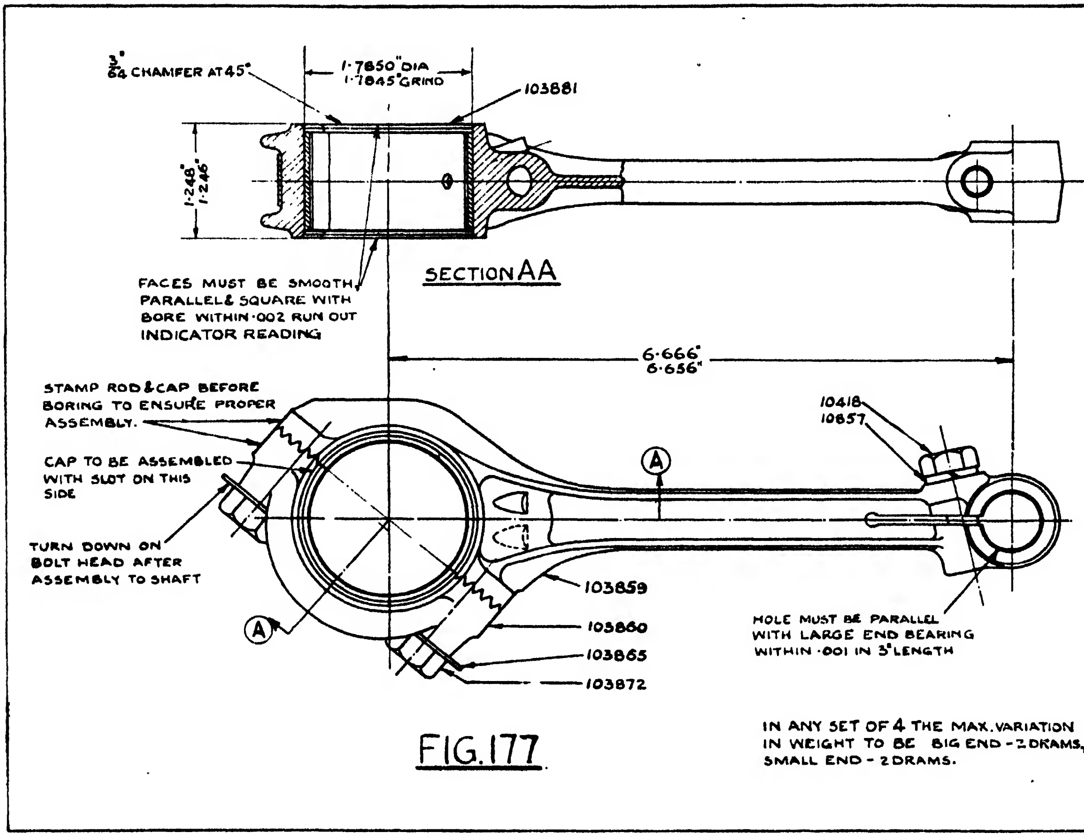
FIG. 175.

PARTIALLY DIMENSIONED ONLY.

(*Fig.* 175 *by permission of Messrs. J. Samuel White & Co. Ltd.*)



(*Fig.* 176 *by permission of Messrs. Morris Motors Ltd.*)



(*Fig. 177 by permission of Messrs. Vauxhall Motors Ltd.*)

in the brasses, into which molten white metal is poured to provide a good bearing, and lubrication is effected by oil pipes passing along the rod (see Chapter VIII). The piston rod is attached to the crosshead on trunnions running in the $3\frac{5}{8}$ in. diameter bores in the 6 in. gap at the forked end. Notice the special bolts, designed for maximum strength by avoiding sharp changes of section and consequent concentration of stresses at the sharp changes. The diameter is reduced to the core diameter except where bearing surfaces are needed and smooth radii are shown, and the screw is prevented from turning by the feather. The special nut is locked in a manner frequently used on heavy engine work, by the set screw in the groove of the nut.

Automobile practice is illustrated by the two rods of figs. 176 and 177. The H section, whilst light, is strong to resist the crushing loads to which the rod is subjected at parts of the stroke, and to withstand the varying bending forces. They are steel drop forgings, carefully heat treated. In both, the big end has a thin steel split bush with a very thin white metal lining, the bushes being prevented from rotating by tabs locating in the grooves (fig. 176). The gudgeon pin is secured in the small end by the screw closing the slot. In other types the pin is free in the connecting rod, but constrained by clips in the grooves in the piston bore (fig. 172). Very close limits of accuracy are held in diameter of bore, centre distance and alignment, and also, the rods used in any one engine must

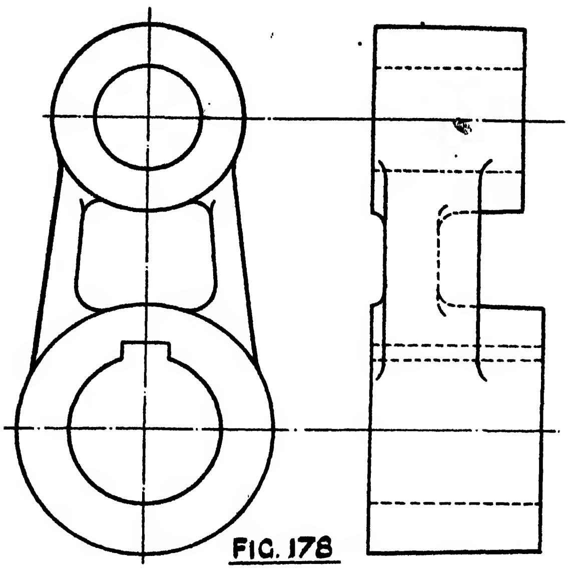


FIG. 178

be of the same weight within a very small tolerance. The small converging holes at the big end act as oil jets, the oil pumped through the crankshaft spraying out over the cylinder bore. The rod and cap, fig. 176, are forged as one stamping with an allowance for the sawcut, and the bore is machined in both parts put together, after slitting. Note how the section is tapered and radiused for easy removal from the die and to avoid severe stresses being set up in the corners. To prevent undercutting at the small end, the shape of cutter for the facing operation is shown. The rod shown in fig. 177 is of unusual design. The double stiffening rib in the cap necessitates the rod and cap being forged in separate parts. The diagonal split makes assembly easier, and the serrated faces ensure alignment.[1]

CRANKS AND SHAFTS

The crank is the mechanism which converts the reciprocating motion of the connecting rod to a rotary motion. In its simplest crude form it is seen on such rough work as toys and treadle machines where it is merely a bent rod, but the crankshaft of a high-speed engine is a job of high precision, which must be perfectly balanced in every way.

For the single cylinder steam engine the crank is usually made separate from the shaft and consists of a steel forging or casting keyed to the shaft, as shown in fig. 178. An alternative type is the disc crank such as that for a motor cycle engine (fig. 179), which consists of two drop forged steel discs, keyed to the separate parts of the crankshaft. The nuts securing both the crankshaft and the crankpin are locked by special locking plates. The two connecting rods run on the one crank pin, and a clearance is allowed by the 4½ in. gaps in the rim of the discs. Balance is given by the sector in the lower part of the disc. (Note the end view shows half inner, half outer face.)

A crank for very heavy work on a three cylinder marine steam engine is shown in fig. 180. The construction, though robust, is quite simple. The forged steel cranks are shrunk on the journals and pins, and then secured by the 1¾ Whit. pins. Shafts such as this are coupled to adjoining shafts by flanged couplings of the type shown in fig. 124*b*, page 98.

Fig. 181 shows a crankshaft for a four-cylinder automobile engine, machined accurately from a carbon steel stamping. It runs in three bearings and is forged with weights which are so shaped to give perfect balance with the webs and crank pins. Holes are drilled to perfect this balance, as shown in the front end view. Such a forging must be carefully worked so that the structure of the metal is not disturbed during forging ; a good forging of this type could be cut along the centre and the surface polished in such a way as to show the smooth flow of the grain (fig. 182).

Note the use of the broken out section to show the recess, the countersink and the bush in the flange, and the use of partial sections to show the varying shape. Observe also how the 30° slope of

[1] See fig. 143, page 112.

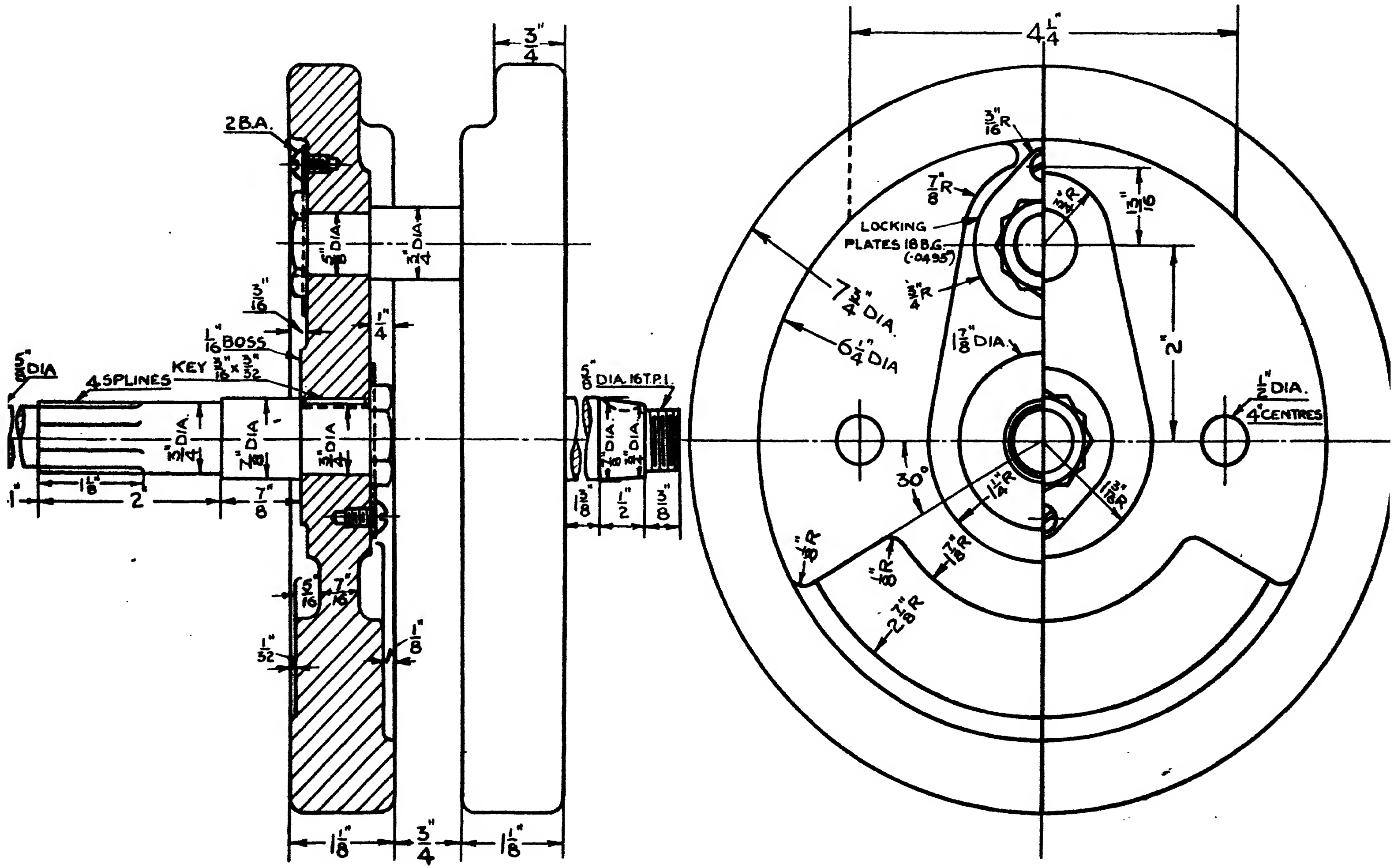


FIG.179 - DISC CRANK

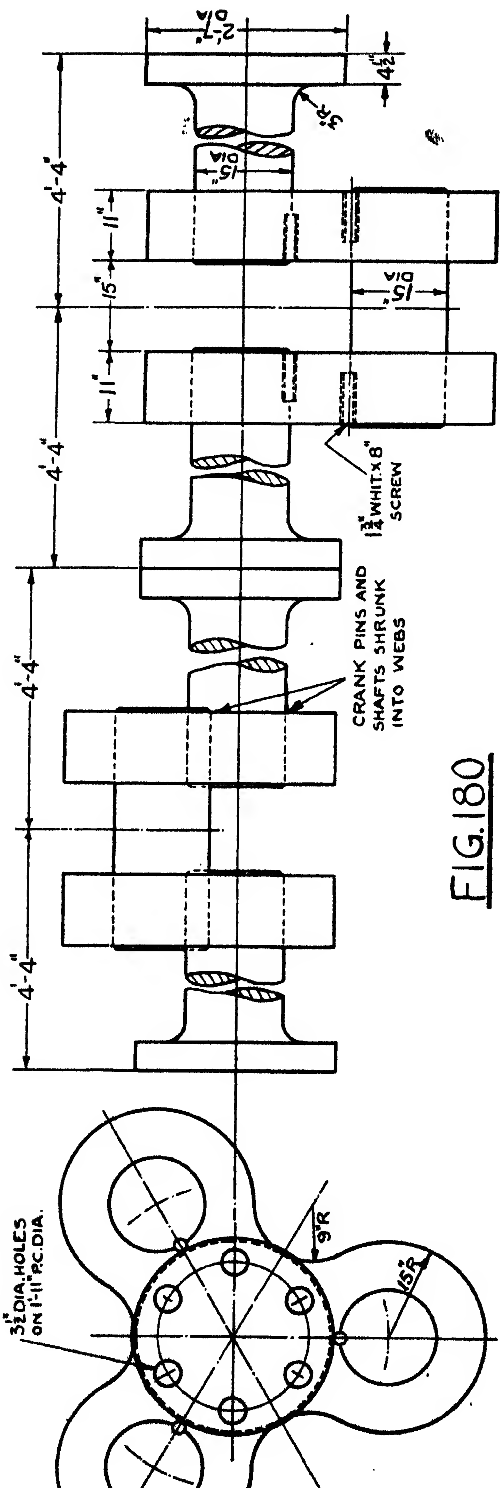


FIG. 180

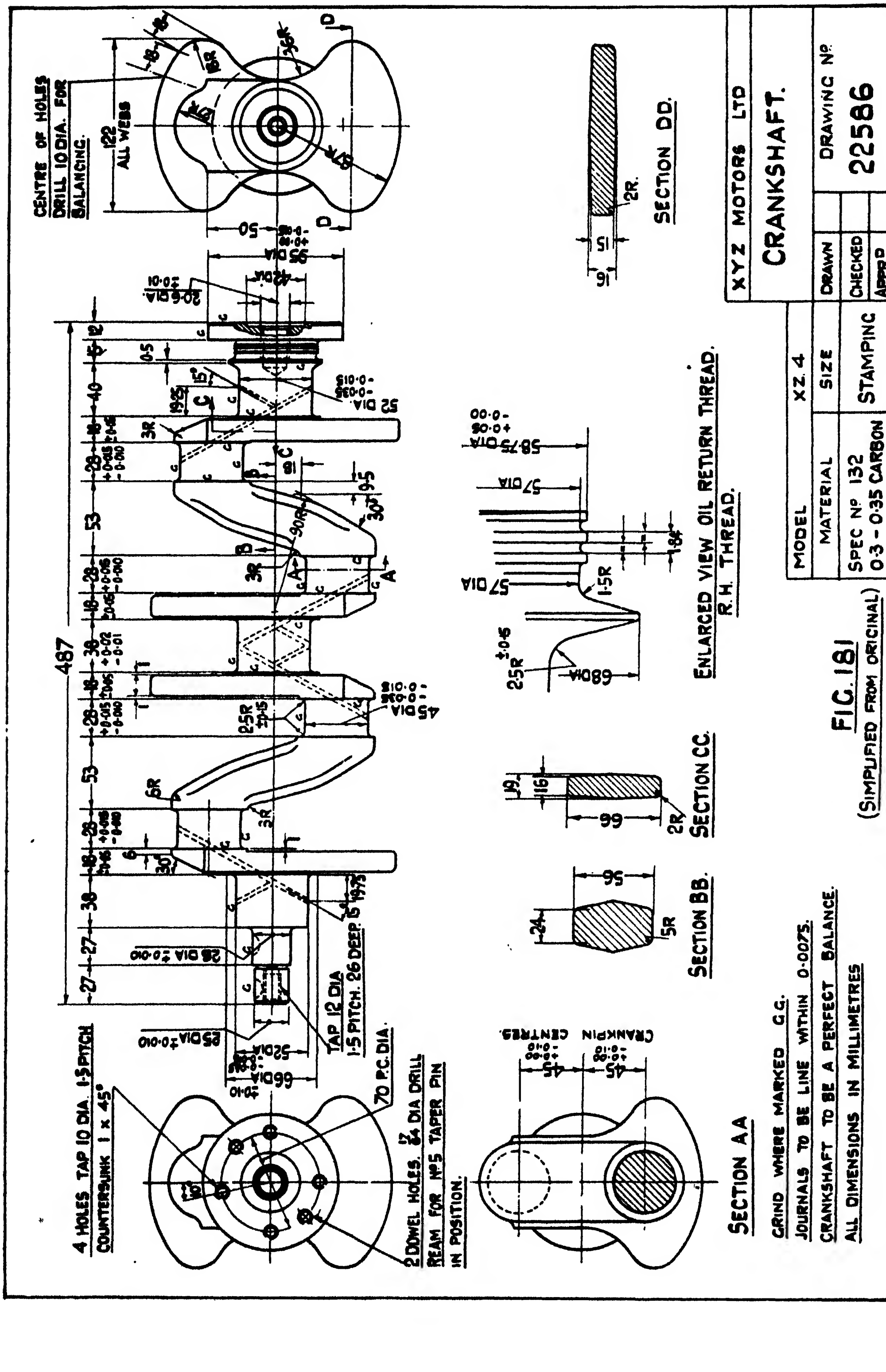
the web is determined by locating a point by the 18 mm. and 9·5 mm. dimensions. Lubricant is pumped through the crankshaft bearing, and thence, by means of the holes in the crankshaft journals, to the crank pins and big end of the connecting rods (see page 138, fig. 176). The small grooved track shown enlarged at the flange end is designed to prevent any oil which may run over the sharp ridge from running beyond to the flanges.

The student becomes so accustomed to thinking of such examples as figs. 178–181 as cranks designed to convert reciprocating motion into rotary motion that he overlooks the fact that **a crank may be required for the reverse process.** For example, suppose a small pumping mechanism needs an oscillating movement of ½ in. A simple device such as fig. 183 would be suitable, for rotation of the keyed shaft would bring the plain shaft to position shown in chain line. This is, in fact, a crank; it is merely an eccentric rod. Such eccentrics are used for the operation of the valves on steam engine cylinders.

VALVE MECHANISMS—ECCENTRICS

In steam engines, the steam is usually admitted to and exhausted from the cylinder by a valve which slides over ports to open or close the passages. It is clear that the movements must be timed to correspond with the movements of the piston, and the valves are therefore moved by the crankshaft. The movement is comparatively small, so a crank of the type in fig. 183 is used, and is known as the eccentric.

The eccentric shown in fig. 184 is for one of the cylinders of the marine engine of which figs. 171, 175, show the piston and connecting rod. The sheave, or eccentric portion, is of cast iron and is keyed to the 6¾ in. diameter crankshaft, and locked by a pointed ⅝ in. Whit. grub screw. The eccentricity of the 14½ in. diameter sheave is 1½ in., hence the valve travel is twice 1½, that is,



(*Fig.* 181 *by permission of Messrs. Morris Motors Ltd.*)

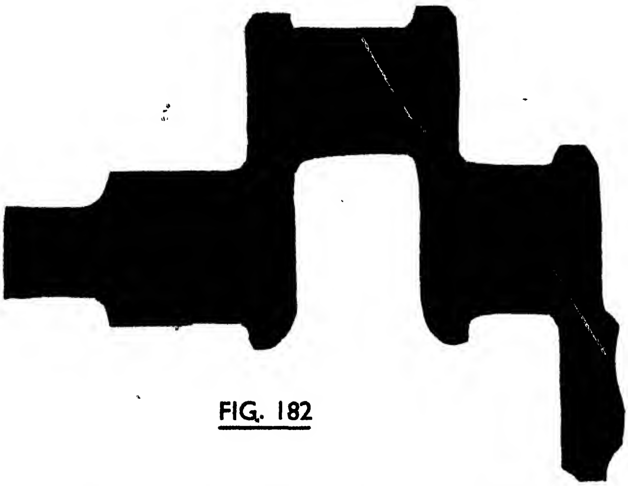


FIG. 182

3 in. Round the sheave are gunmetal straps which have white metal facings cast into dovetail slots. The two parts of the strap are bolted round the sheave, and the assembly is secured to the valve rod by mild steel studs and nuts.

To allow for wear and adjustment

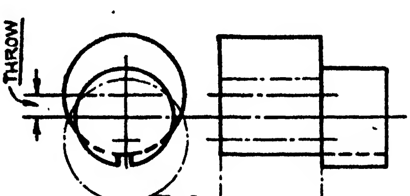


FIG. 183

gunmetal liners are fitted and secured by dowels. The special bolts, of mild steel, are prevented from turning by a snug, and locked by two nuts put on in the theoretically correct order.

Lubricant is fed to the sheave from an oil cup on the valve spindle through oil pipes, to the counterbored oil holes.

The eccentric for the high-pressure cylinder for this engine differs from those for the intermediate and low-pressure cylinders as it runs on a overhanging pin of the crankshaft, and it is therefore made with the sheave in one piece, instead of being split and bolted as shown. In addition the valves are of a different type and need a 3½ in. travel.

I.C. ENGINE VALVE GEAR

The valves are usually of the mushroom type, actuated by rocker arms. Figs. 185–186 show a valve and rocker arm for the marine diesel engine, of which fig. 172 shows the piston. The arms are operated by push rods and tappets moved by a camshaft which, in turn, is driven directly from the crankshaft. The rocker arm, a forging of stiff " I " section, runs on a ball bearing. The valves are of special steel, retaining its strength and toughness at a very high temperature, since the actual combustion takes place in a cylinder head. Often special measures are taken to induce more rapid conduction of heat, away from the valve face along the stem.

THE SLIDE VALVE

The steam supply to an engine cylinder is controlled by a valve which covers or opens ports to the steam chest and exhaust port successively. Fig. 187 shows the action of a simple slide valve which consists of a cast iron box moving over the ports. Since the pressure on a large valve face causes heavy frictional losses, this type is often replaced by the **piston valve,** especially for high-pressure cylinders. In these, the pressure is acting on the curved surface of a cylinder, and is therefore balanced so that the frictional forces are reduced. A piston valve is shown in fig. 188.

CROSSHEADS

It has been mentioned that the piston rod of a steam engine meets the connecting rod at a pin joint, called the crosshead (see fig. 170, page 133). It is obviously necessary to constrain the movement of this crosshead to keep the piston rod in alignment, and to allow free reciprocating movement. From the elementary study of mechanics, it is

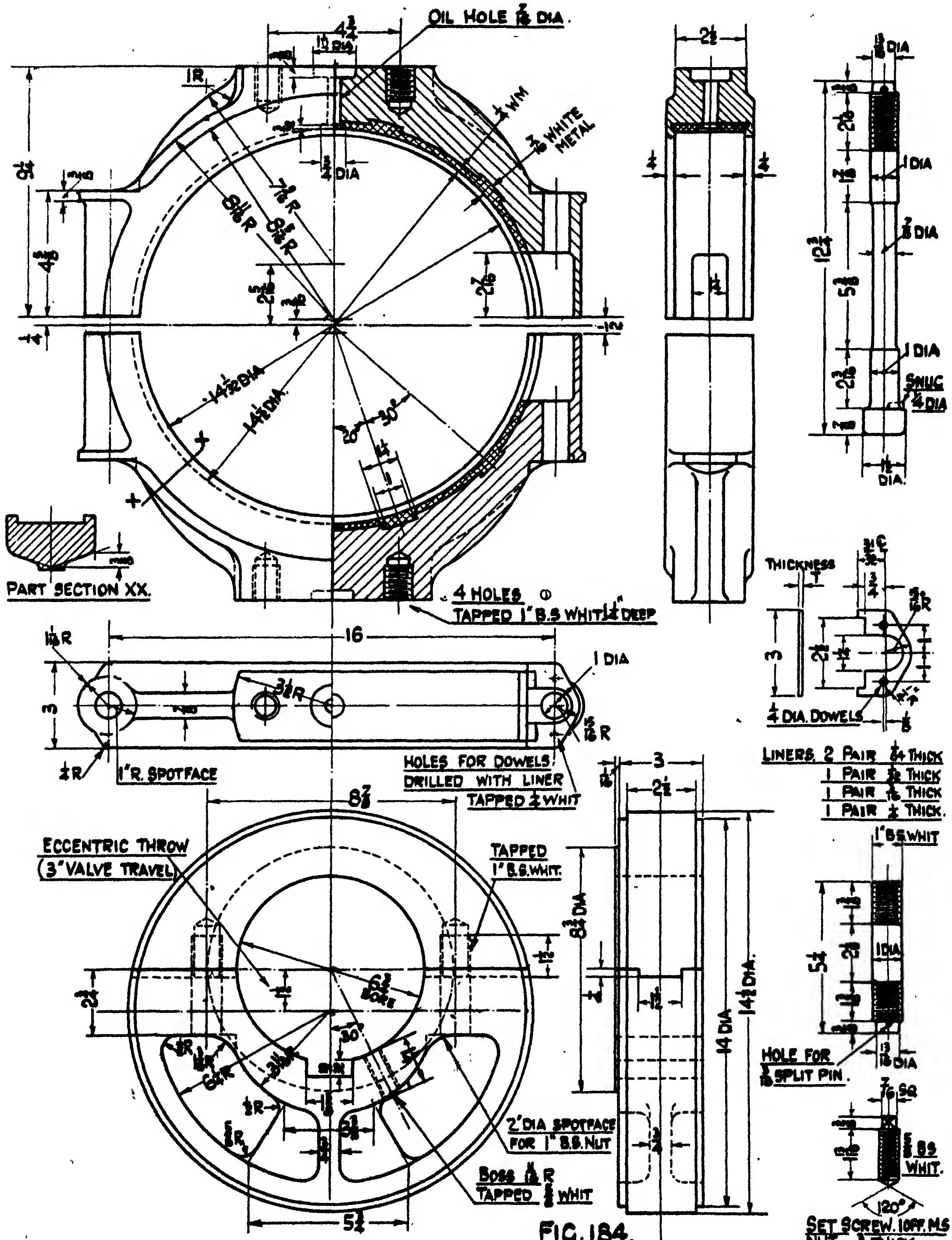


FIG. 184.

(Figs. 184 and 189 by permission of Messrs. J. Samuel White & Co. Ltd.)

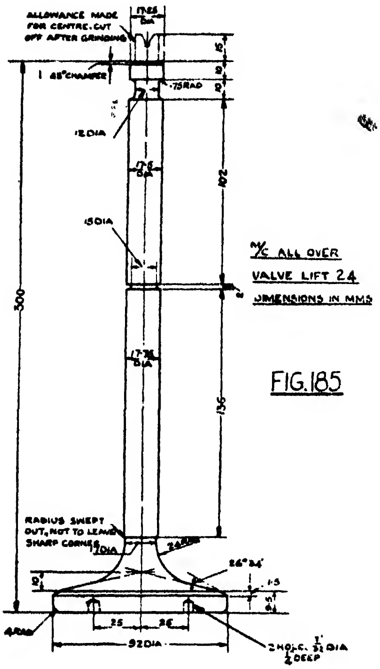


FIG.185

clear that this joint is subjected to considerable forces.

The connecting rod of fig. 175 runs on the trunnions of the forged steel crosshead shown in fig. 189, and when assembled, the 3 in. × 8⅛ in. rectangular opening slides over lubricated guide rods on its white metal faced slippers. This is a very simple and robust type of crosshead, often used in marine work.

The efficient operation of such steam engine details depends upon the careful fitting and good workmanship.

There are several types of crosshead to suit different types of stationary engine or locomotive or marine engines. Many have double guide bars as shown in the arrangement drawing of the locomotive crosshead fig. 190. Notice in this drawing the application of the cottered joint mentioned in Chapter V.

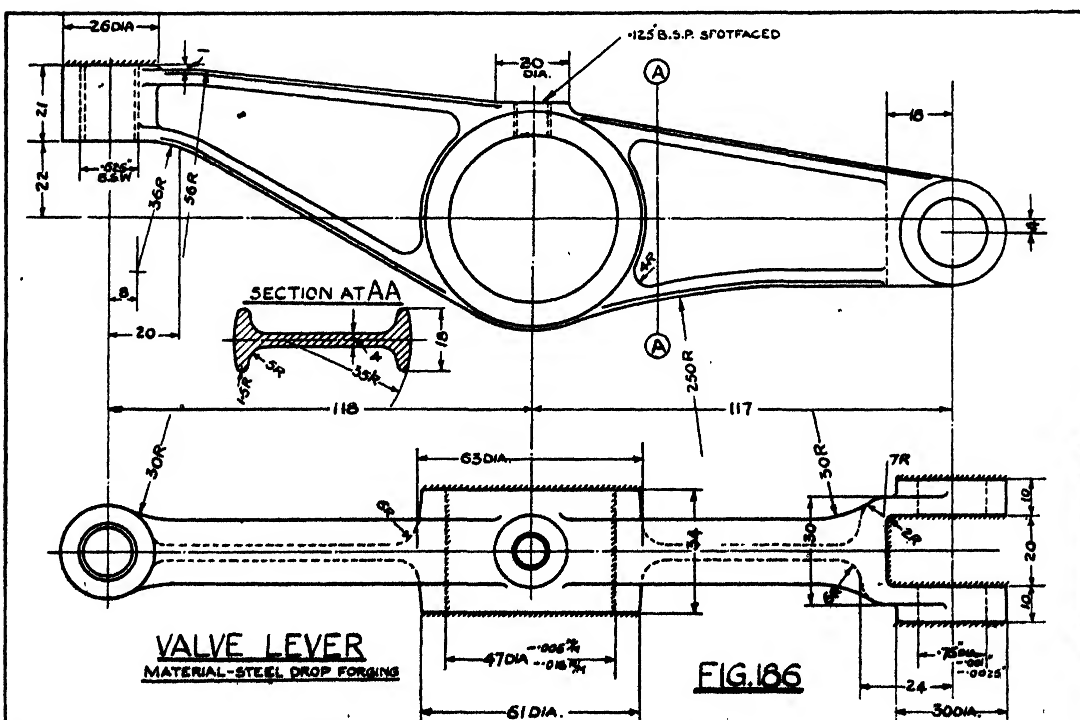


FIG.186

(*Figs.* 185 *and* 186 *by permission of Messrs. W. H. Allen, Sons & Co. Ltd.*)

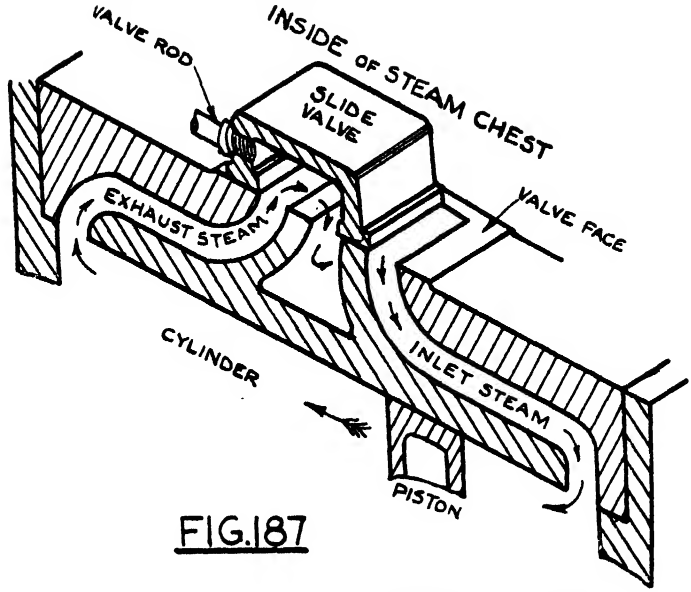


FIG. 187

EXERCISE XV

(1) Make a working drawing of the locomotive piston of outside diameter $7\frac{7}{8}$ in. (fig. 191*a*). Give half sectional end elevation and front view. Half full size.

(2) Make a working drawing of the motor cycle piston (fig. 191*b*).

(3) Prepare an assembly drawing of a marine engine piston (see fig. 171) for a 15 in. cylinder fitted with rings as shown. Give half sectional elevation and end elevation. Scale half full size, and plan with ring removed.

(4) Make a detail drawing of one of the "brasses" of the marine engine rod (fig. 175).

(5) Assemble the connecting rod for the marine diesel engine (fig. 192). Give two views and schedule.

(6) Make a forging drawing for the 4-cylinder automobile engine crankshaft (fig. 181).

(7) Assemble the rod (fig. 176) with lined bushes and bolts; the crank pin diameter being 45 mm. The bolts have castle nuts.

(8) Make an assembly drawing of the balanced crankshaft for a petrol engine (fig. 193).

(9) Make a complete working drawing of a crankshaft for a two-cylinder air compresser to give a $4\frac{1}{2}$ in. stroke. Further particulars are given in fig. 194.

(10) Assemble the eccentric (fig. 184) for a marine steam engine. Give two views and schedule of parts.

(11) Make a detail drawing of an eccentric sheave machined in one piece to give a $2\frac{1}{2}$ in. stroke to the valve. Bore, 6 in. diameter; outside diameter, $13\frac{1}{2}$ in.; thickness of sheave, $2\frac{3}{4}$ in.

(12) Prepare a working drawing of the slide valve (fig. 195).

(13) A layout of the scheme for the valve gear of an internal combustion engine is given in fig. 196. From this, prepare a working drawing of a suitable rocker arm (see fig. 186, page 146).

(14) Make complete detail drawings of the locomotive crosshead (fig. 190), showing elevation, half sectional end elevation and half sectional plan. Show oil grooves in the slipper face.

(15) Make forging drawings for the parts of the connecting rod (fig. 177).

(16) Prepare a detail drawing of the disc crank (fig. 179).

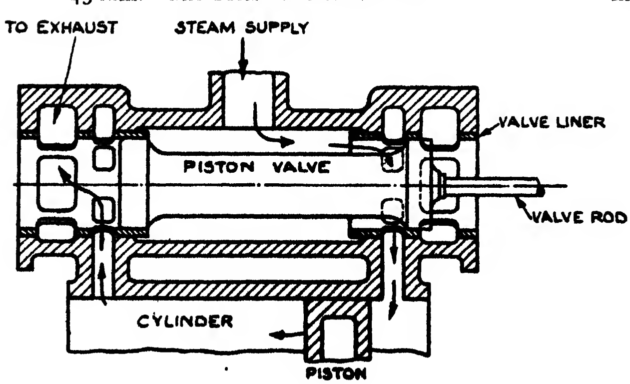


FIG. 188

WATER AND STEAM VALVES

In Chapter VII reference was made to the various practices adopted in steam, gas and water pipe work. To control the flow of the fluids in the pipes different types of valves are used, some of which are illustrated to show the modern practice in this class of work.

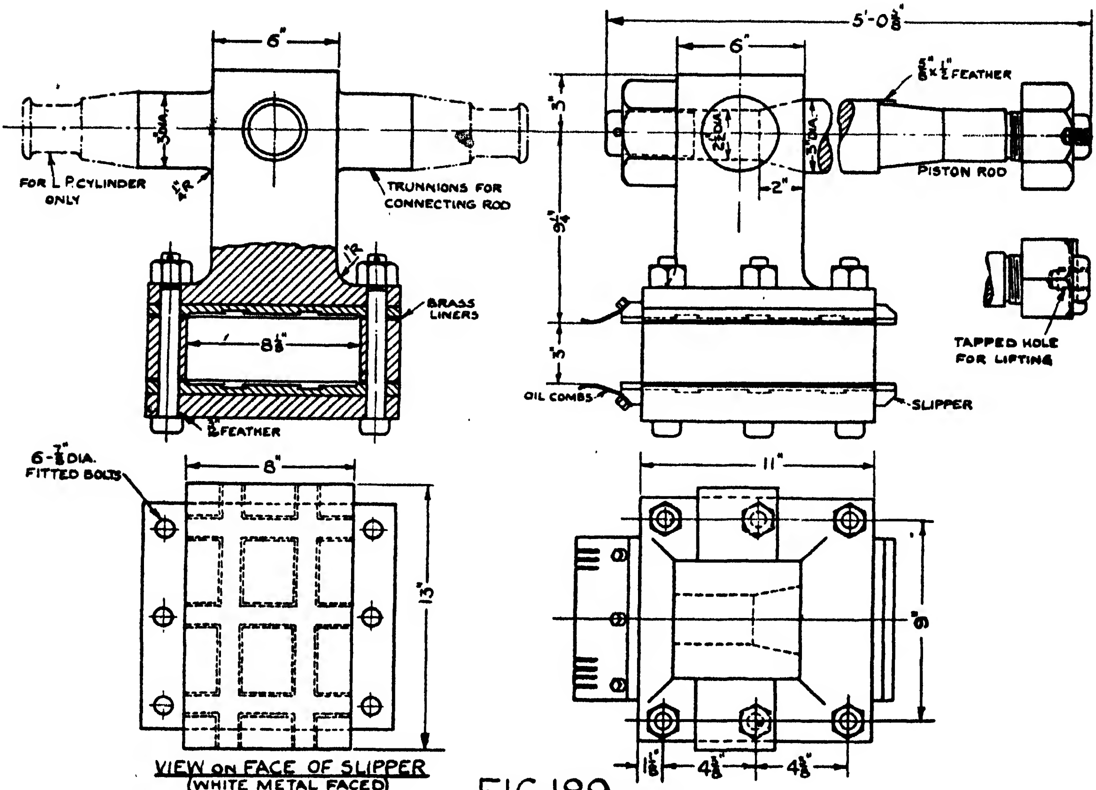


FIG. 189

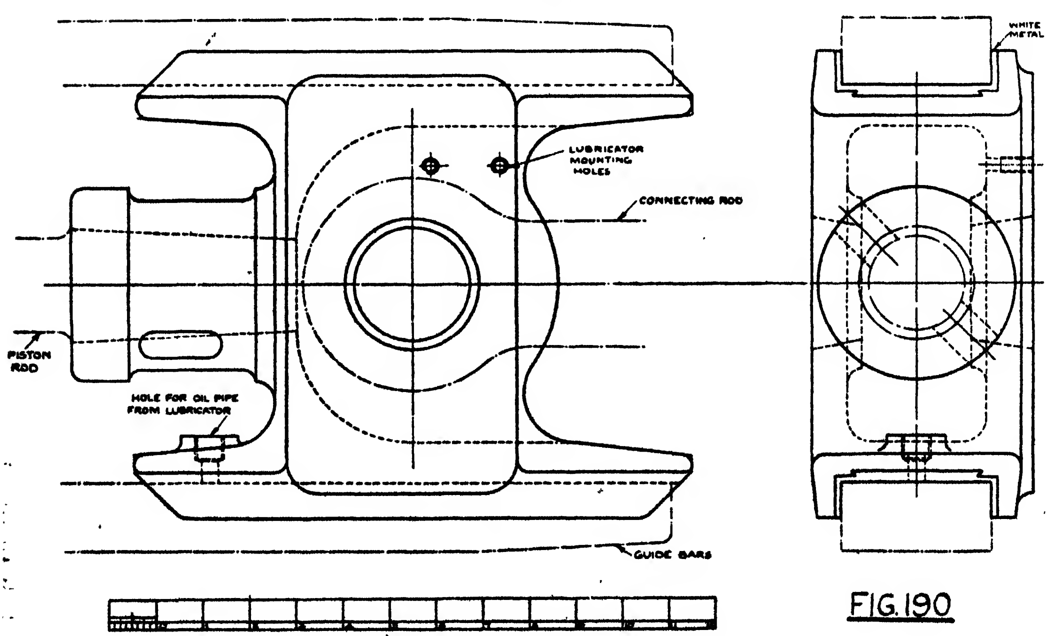


FIG. 190

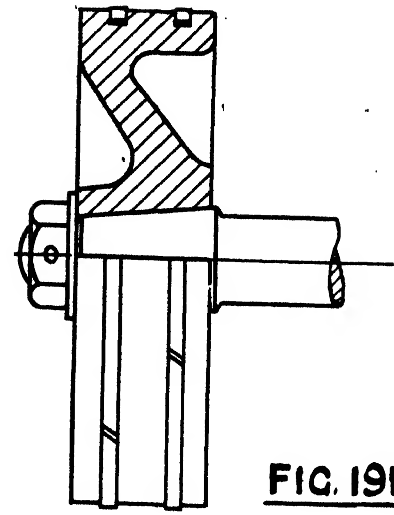
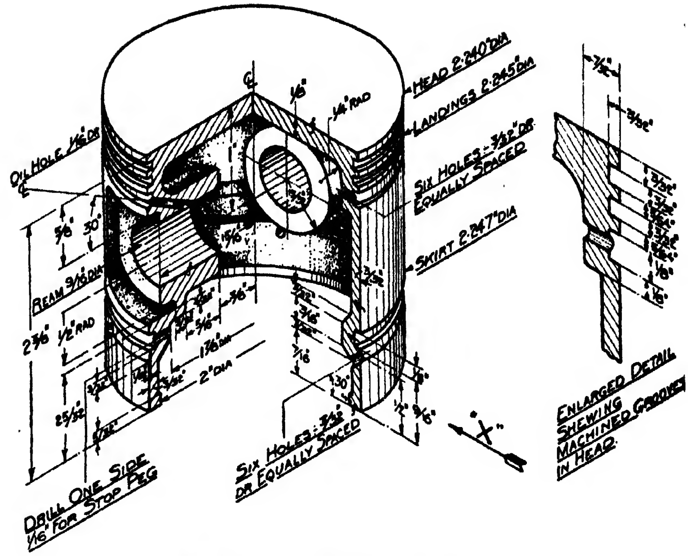


FIG. 191a



PISTON FOR 2¼" DIA CYLINDER.
ALUMINIUM-BASE ALLOY DIE-CAST
MACHINED WHERE MARKED f
FILLETS & RADII 3/32"
BOTH GUDGEON PIN BOSSES IDENTICAL

FIG. 191b

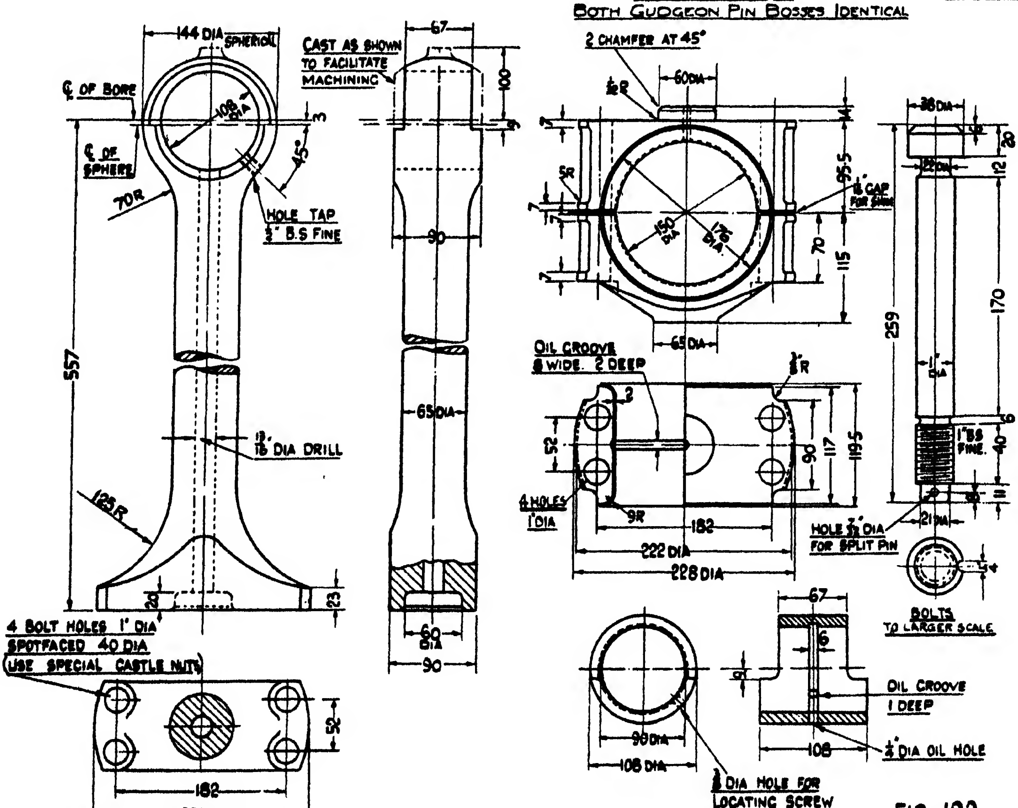
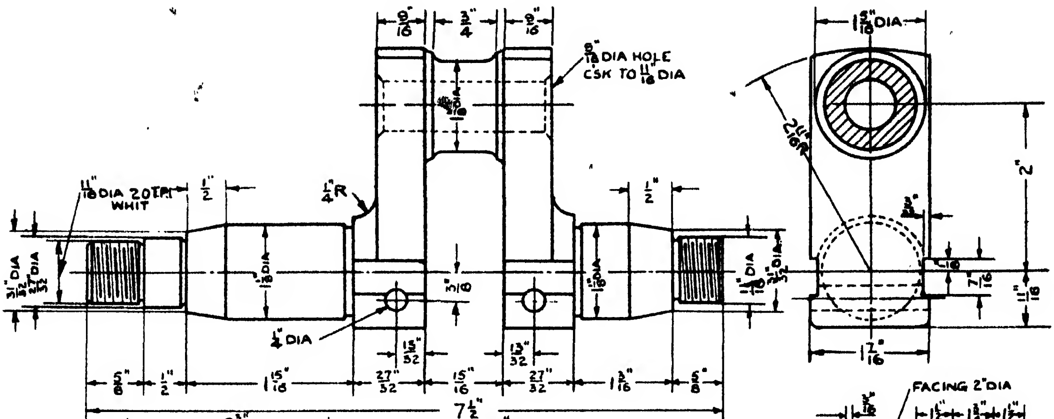


FIG. 192.
SIMPLIFIED FROM ORIGINAL.

(Fig. 192 by permission of Messrs. W. H. Allen, Sons & Co. Ltd.)



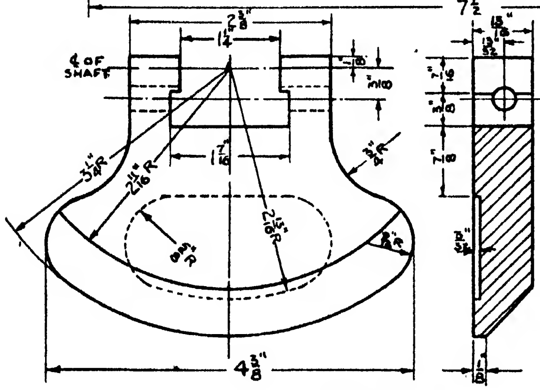


FIG. 193

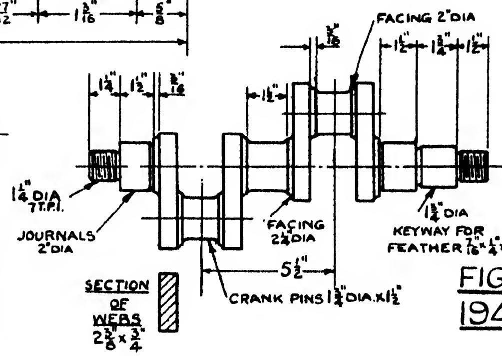


FIG. 194

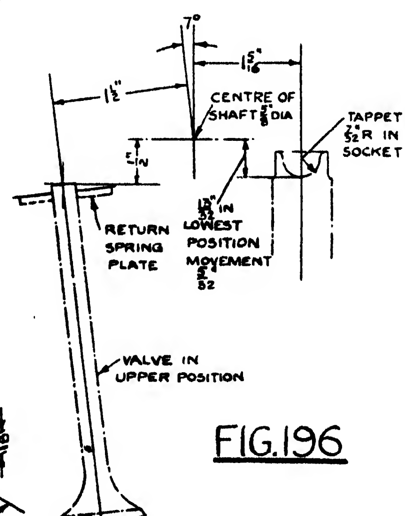


FIG. 196

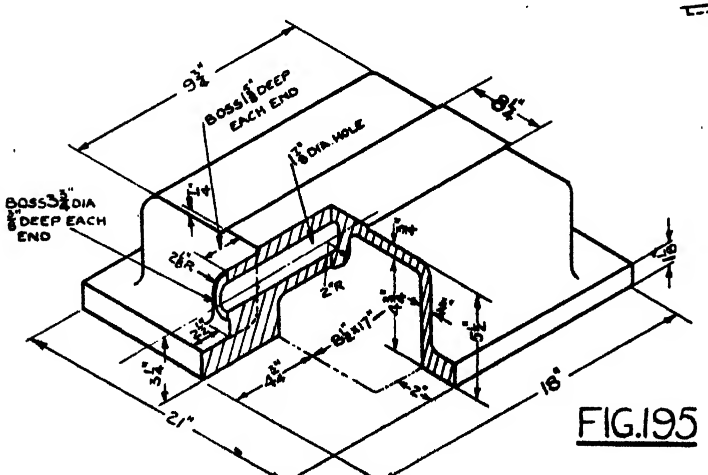


FIG. 195

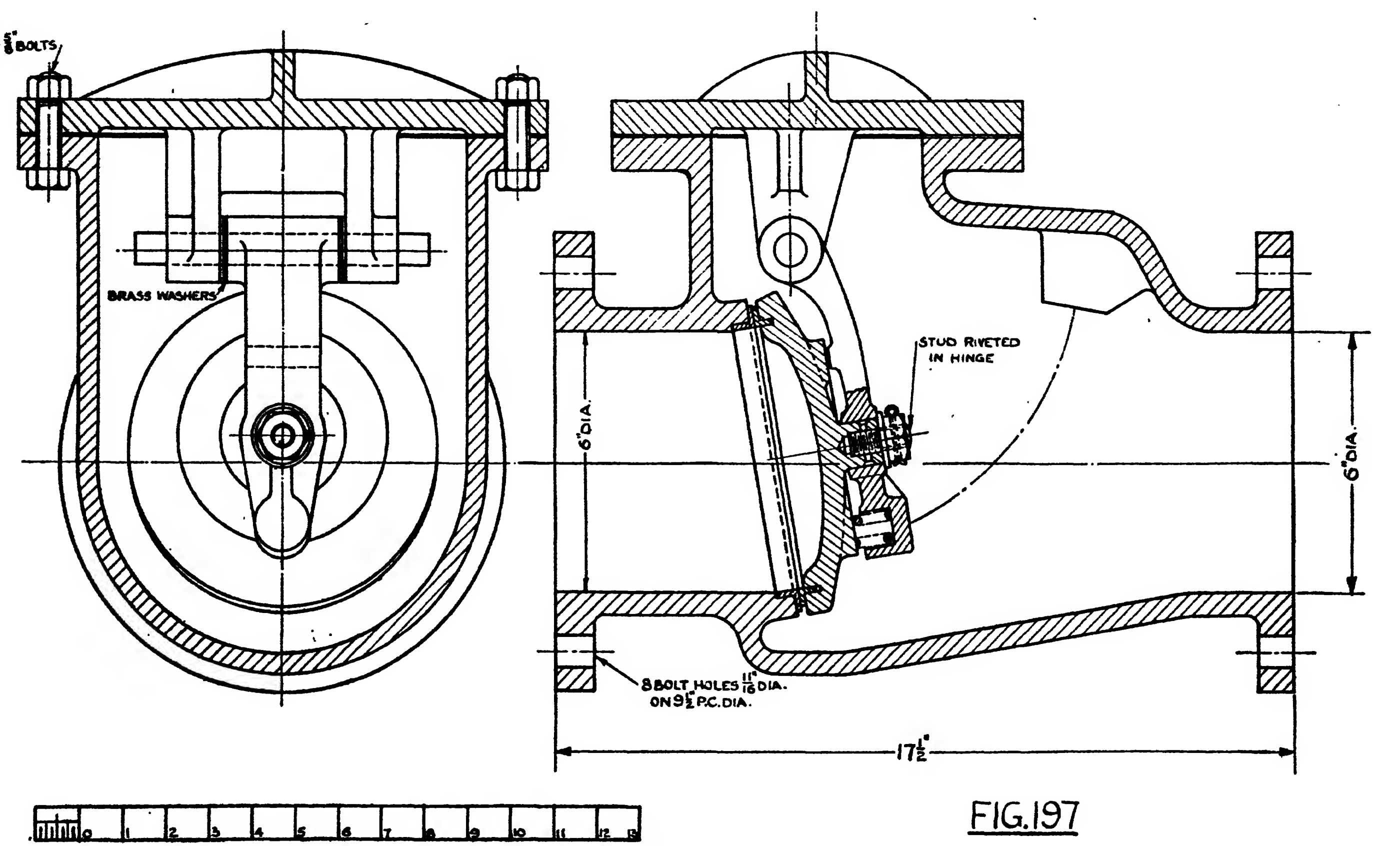
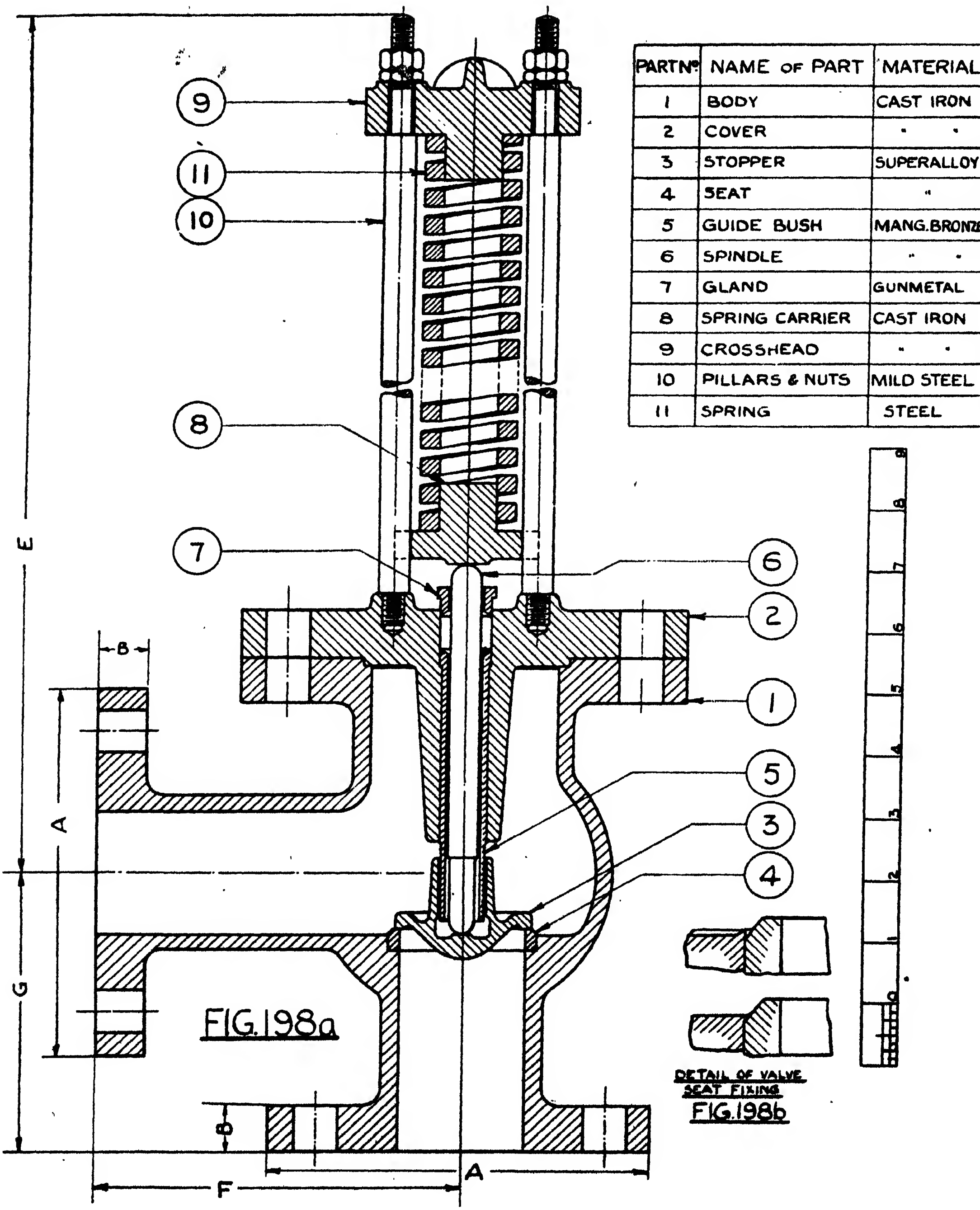


FIG. 197

(*Figs.* 197, 198, *and* 200 *by permission of Messrs. J. Blakeborough & Sons Ltd.*)



PART No.	NAME OF PART	MATERIAL
1	BODY	CAST IRON
2	COVER	" "
3	STOPPER	SUPERALLOY
4	SEAT	"
5	GUIDE BUSH	MANG. BRONZE
6	SPINDLE	" "
7	GLAND	GUNMETAL
8	SPRING CARRIER	CAST IRON
9	CROSSHEAD	" "
10	PILLARS & NUTS	MILD STEEL
11	SPRING	STEEL

FIG. 198a

DETAIL OF VALVE SEAT FIXING

FIG. 198b

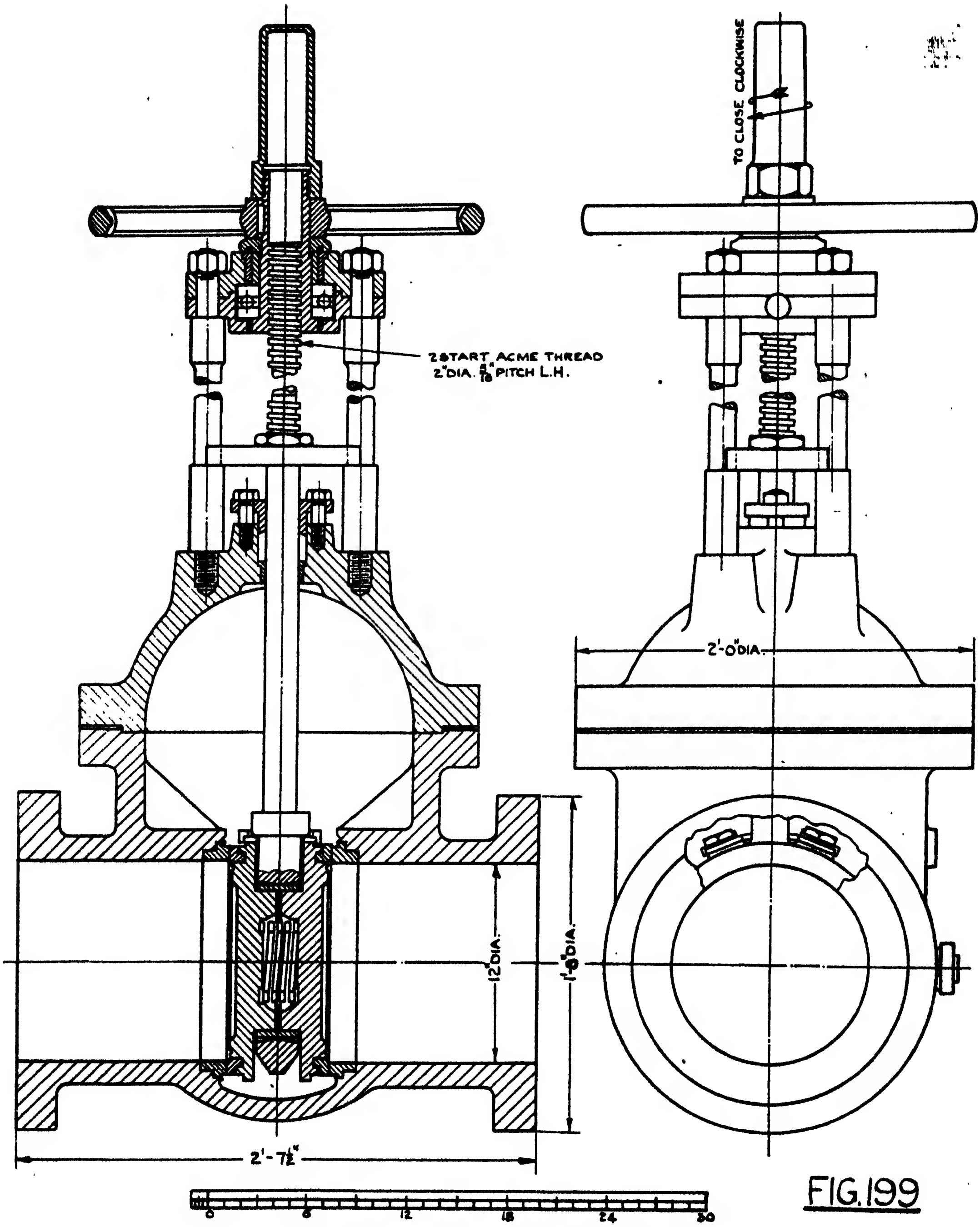


FIG. 199

(*Fig. 199 by permission of Messrs. Hopkinsons Ltd.*)

Fig. 197 shows a **reflux valve** which allows a flow in one direction only, any return flow immediately closing the valve. This type is used for various fluids in standard sizes from 1½ in. to 24 in. bore. For the smaller sizes the door is of gunmetal, as well as the valve faces, but for the larger, it is of cast iron; the body, cover and hinge are all of cast iron. The valve gives a free flow up to the maximum when the hinged door comes up against the stop.

A **relief valve** which opens when the pressure under the valve reaches a predetermined value is shown in fig. 198*a*. It is made of cast iron for water pressures up to 150 lb. per sq. in., and of cast steel for water up to 250 lb. per sq. in. Similar valves are used for steam. The valve, or stopper, and the valve seat are made of a special nickel alloy, the latter being spun in the valve seat to the valve body as in fig. 198*b*. Notice how the inlet side of the stopper is curved to promote a ready flow and to avoid turbulence when the valve opens; note also the long, shielded spindle. The release pressure may be adjusted by movement of the locknuts on the vertical pillars. Relief valves are made from ½ in. to 12 in. bore, and similar valves may be used having a lever and weight in place of the spring for control of release pressure.

Parallel slide valves (fig. 199) have the advantage of giving a full uninterrupted bore when full open, and are used very extensively for water or steam from the very smallest sizes up to 16 in. bore for pressures up to 350 lb. per sq. in. and high temperature superheated steam. The example shown has a cast steel body, and is suitable for steam flow; it has disc facings of a special nickel bronze alloy, spun into the mild steel discs. Pressure against the seatings, of the same alloy, is ensured by the steel spring. The discs are raised by the belt eye fixed to the spindle, and are kept together by the disc holder encircling the boss on each part. Observe the use of a thrust race to ensure that the sleeve rotates freely when the handwheel is turned. The left-hand thread on the stainless steel spindle allows the clockwise rotation of the handwheel to close the valve in common with standard valve practice. Since the nut and not the screw is turned the left-hand thread is necessary for this purpose. The sliding crosshead not only arrests the travel of the discs when closed, but also serves as an indicator.

Sluice valves of similar construction, often having a wedge-shaped slide, are used for water work in much larger sizes.

EXERCISE XVI

(1) Prepare a detail drawing of the reflux valve body (fig. 197). Show a sectional elevation, half sectional end elevation and a full plan view.

(2) Make a detail drawing of the cover for the valve (fig. 197).

(3) Detail the hinge and the door (fig. 197) and give a sub-assembly of these components with facing stud, nut, pins and spring.

(4) Prepare a sectional elevation, half sectional end elevation and a plan of the body, for the relief valve (fig. 198a). Make provision for the insertion of the valve seat.

(5) Detail the cover for valve (fig. 198a). How would the gland be retained in position?

(6) Make an assembly drawing showing sectional elevation and full end elevation of a relief valve with 2½ in. bore. Dimensions as follows: A 6½ in., B ¾ in., E 21 in., F 6½ in., G 5 in.

(7) Fig. 200 gives a sub-assembly of the dashpot unit for an auto isolating valve. Using the scale, make working detail drawings of the:

(i) stopper head	(iv) piston
(ii) valve face	(v) spindle
(iii) nose piece	(vi) dashpot

(Note the method of spinning the valve face in the head.)

(8) Details for a small gate valve are shown in fig. 201. Assemble these details, showing sectional elevation and half sectional end elevation.

(9) A sketch of a small stop valve is given in fig. 202*a*. Using the valve body (fig. 202*b*), prepare an assembly of a 1½ in. stop valve.

(10) Modify the stop cock shown in fig. 203 to suit a 1½ in. bore pipe line having B.S.P. male thread on each end (*i.e.*, the valve must have tapped hexagonal ends instead of flanges).

MACHINE TOOLS

About 150 years ago, when mechanisation in industry began, the pioneers

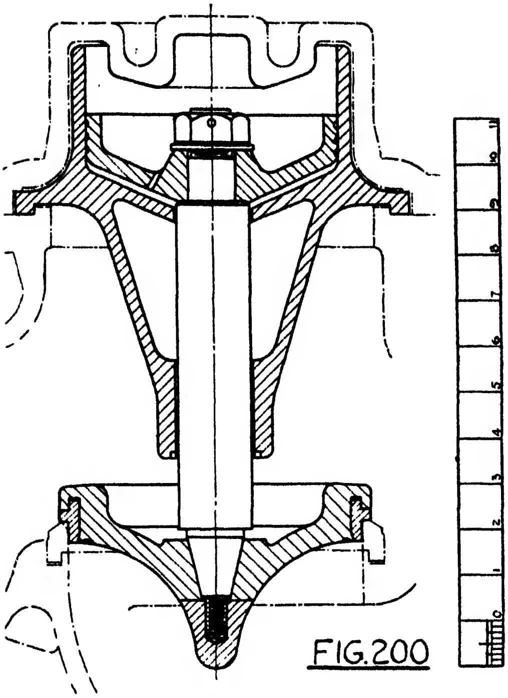


FIG. 200

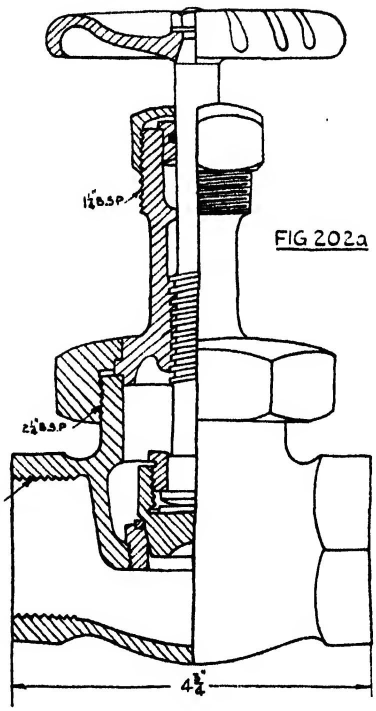


FIG 202a

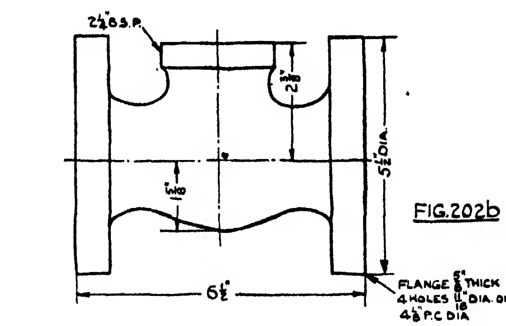


FIG. 202b

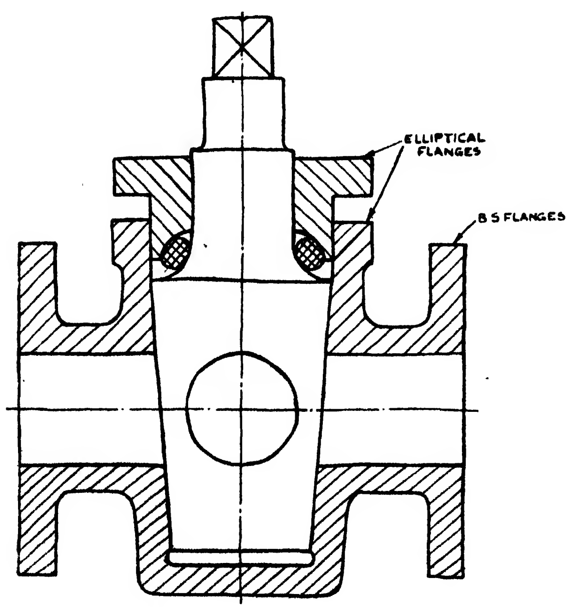


FIG. 203

were limited by the inadequacy of their machine tools. For example, James Watt wrote exultingly that they had been able to achieve such a fit between a piston and cylinder that they " could not get so much as an old shilling between." Obviously the accuracy of the machine tool governs the accuracy of the product, and modern precision work is possible only because of the high standard of design and workmanship in the machine tool industry. This precision is particularly marked in the rigidity of the checks on accuracy of

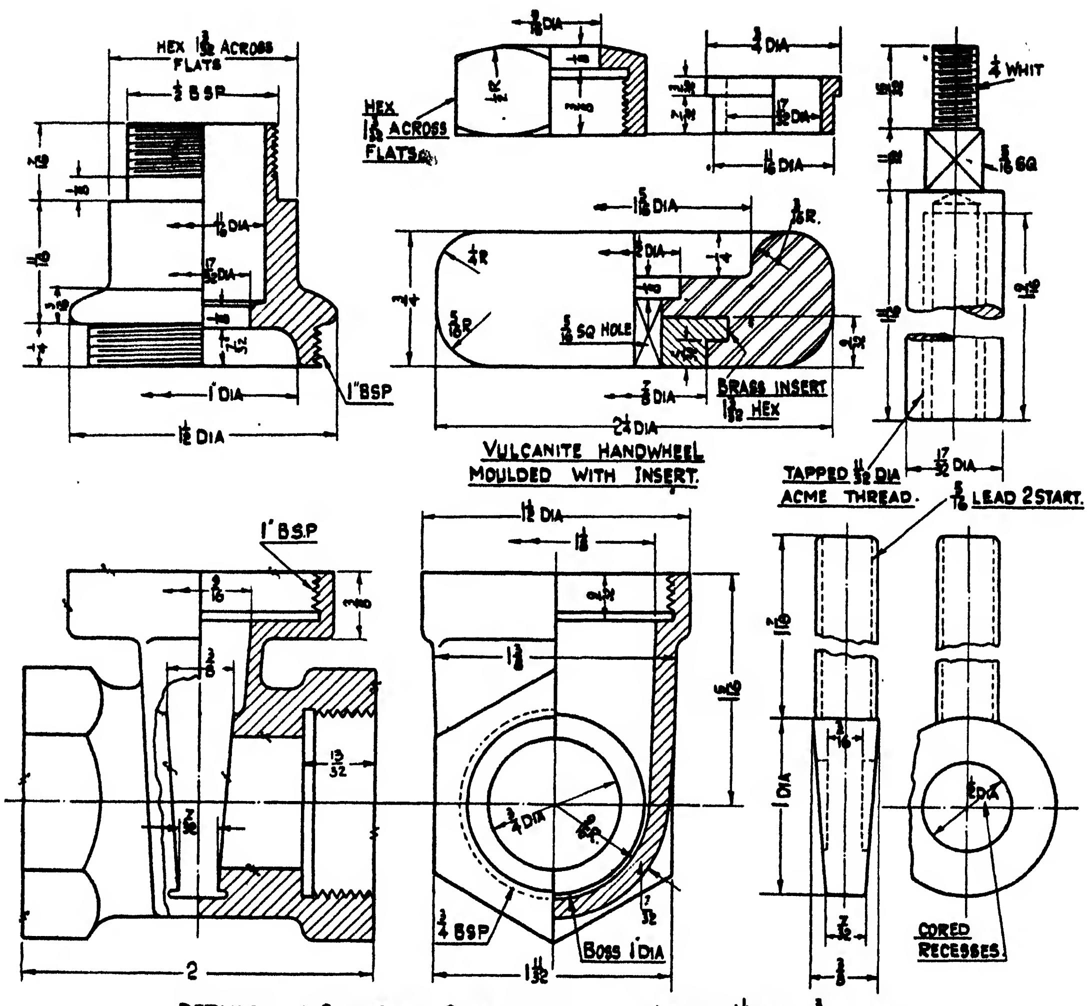


FIG 201

alignment, tolerances of less than 0·001 in. in a length of three or four feet or more being common.

Machine tools are now produced in immense variety, both for general and for special purposes, and the student can only learn of this class of work by actual experience. With increasing speed of cutting, and the widely varying nature of materials cut, the machine tool maker must ensure, in addition to accuracy of workmanship, rigidity of construction, avoidance of vibration, freedom of movement, ample clearance for swarf and coolant, and generally, wide range and easily changed speed. It is impossible to discuss all these features in a small section of a book, but the examples shown illustrate some of the points. By thoughtful observation in the machine shop, the student will be able to see how the machine tool designer strives to achieve these essentials by careful consideration of both large and small details.

Example (i). A robust spindle, of

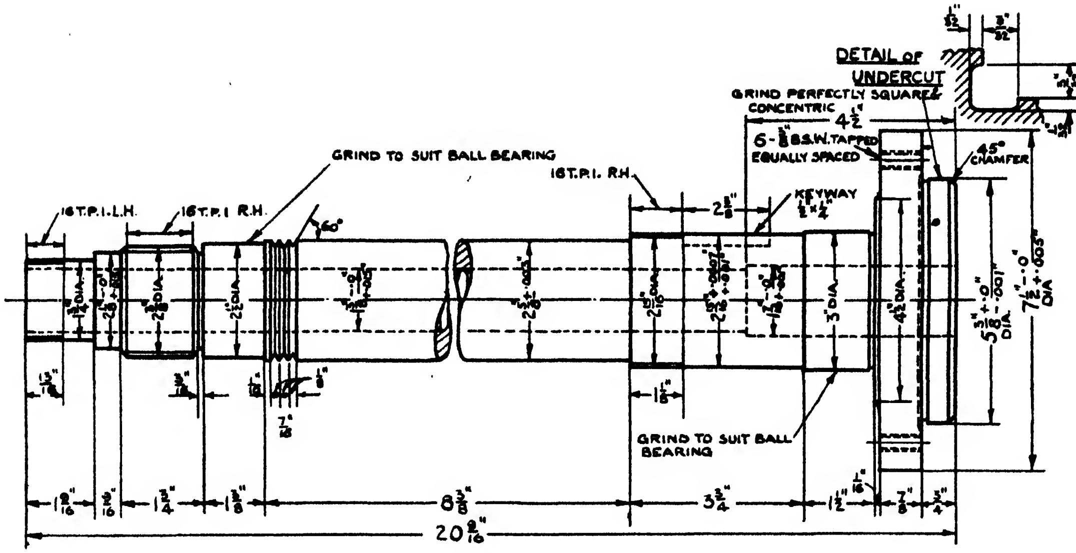


FIG.204

(*Fig. 204 by permission of Messrs. The Churchill Machine Tool Co. Ltd.*)

hardened 0·5 per cent. carbon steel for an internal grinder is shown in fig. 204, a simple, yet vital detail. The design is rigid, with substantial bearing diameter, whilst tolerances of 0·0003 in. call for accurate workmanship on the more important diameter.

The undercut in both diameter and face on the $5\frac{5}{8}$ in. diameter spigot is a common device where it is necessary to ensure that a mating part will fit snugly into the corner, avoiding the possibility of a tiny radius on the grinding wheel preventing the part fitting right up to the face. Very shallow recesses are frequently made on diameters with a shouldered end to permit the wheel to grind the whole length without a radius in the corner. This one view is sufficient for any one familiar with machine processes to determine the type of key way indicated (see Chapter VIII, page 96). Note that the method of representing screw threads is very suitable for the large diameter small pitch threads and also marks distinctly the Vee grooves which are not a thread, but an oil trap.

Example (ii). The careful thought which a designer gives to promote accuracy in erection is illustrated by the feed worm bracket for a plano-milling machine in fig. 205. The bracket has two steps machined on the bosses at each end, for the express purpose of aiding the erection. The steps are machined in the exact vertical plane of the worm shaft axis and positioning is effected by gauge blocks from the machined face of the bed seating. For permanent use the blocks are replaced by shims of the same thickness. Shims are used in a similar way for setting the height of the bracket.

Example (iii). The base for a large vertical milling machine is shown in fig. 206. Principles of design are well illustrated by this example, which is of substantial construction, with the main sliding surfaces and tableguides directly under the milling spindle, giving ideal support under the cut. Two well spread auxiliary surfaces ensure stability. The slide ways are very hard, of special quality iron. Discharge chutes for the chip are incorporated in the design.

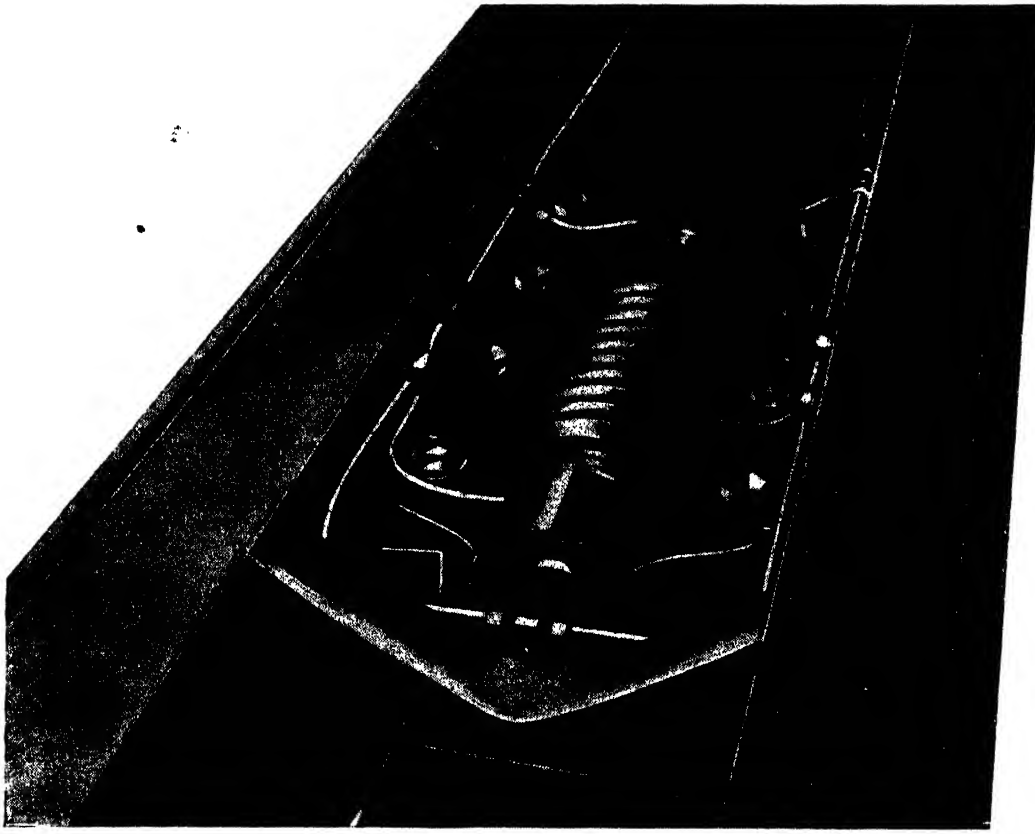


FIG. 205

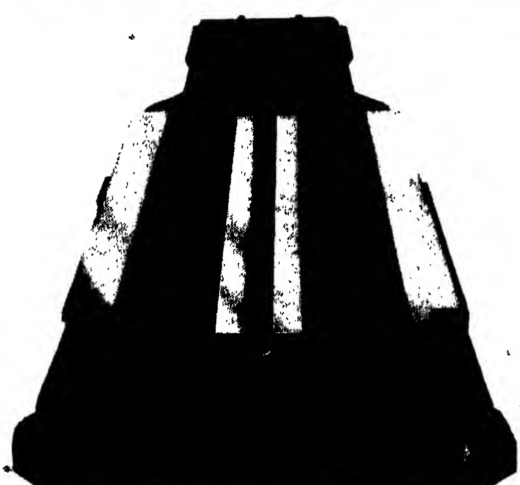


FIG. 206

(Figs. 205 and 206 by permission of Messrs. Kendall & Gent (1920) *Ltd.)*

The extension on which the column is mounted forms the coolant tank, into which the coolant drains from the drip channel round the base.

EXERCISE XVII

(1) Fig. 207 shows a fixed stay for a large grinding machine. A stay of similar design is required for a machine of 10 in. from flat bed to centre and $9\frac{1}{4}$ in. from centre to centre of Vee, instead of $13\frac{3}{8}$ in. and $13\frac{1}{4}$ in. respectively. The Vee is set at the same angle off a $1\frac{3}{4}$ in. bar $1\frac{7}{8}$ in. above the flat surface instead of 2 in. bar. The stay is to take work of maximum size of 5 in. diameter. Make a detail of the stay.

(2) A plate collet chuck detail for a grinding machine (fig. 208) is to be modified to suit a different chuck, which necessitates the following alterations : angle 15° becomes 20°, $16\frac{3}{8}$ in. diameter to be $12\frac{1}{4}$ in., $6\frac{3}{8}$ in. diameter to be $4\frac{7}{8}$ in., $1\frac{5}{16}$ in. depth to be $1\frac{1}{16}$ in. Draw the modified detail, making further alterations as required. (*Note that in order to make the casting stiff enough to stand the machining*

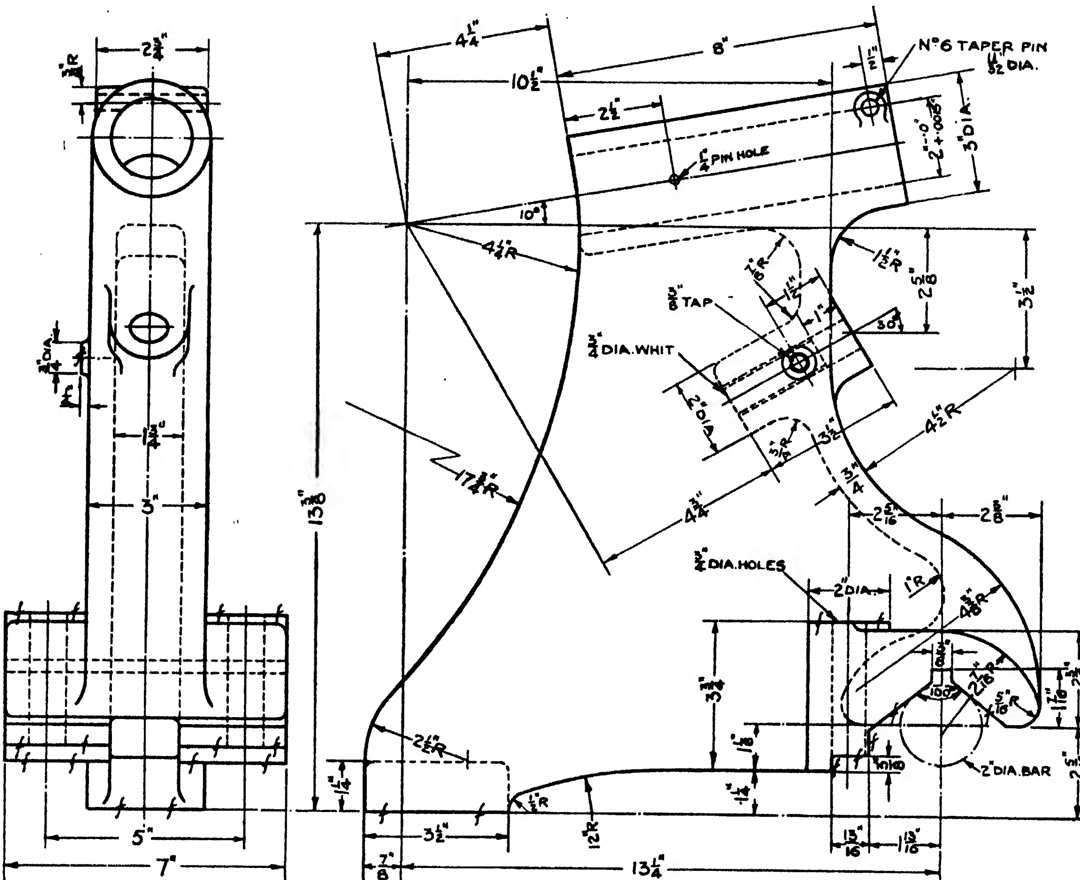


FIG.207

(Fig. 207 by permission of Messrs. The Churchill Machine Tool Co. Ltd.)

operation, the inner ring is cast complete, and the unwanted portions removed after turning, milling and grinding. This precaution is occasionally necessary on fragile castings.)

(3) Modify the knee tool holder (fig. 209) to suit the turret face with a hole for pilot bar shown.

(4) Fig. 210 gives a freehand drawing of a double Vee tool holder for a capstan lathe. Make detail drawings properly dimensioned of: (i) tool post, (ii) Vee holder, (iii) body.

(5) Make an assembly drawing of the tool holder of question 4.

ADDITIONAL EXERCISES

EXERCISE XVIII

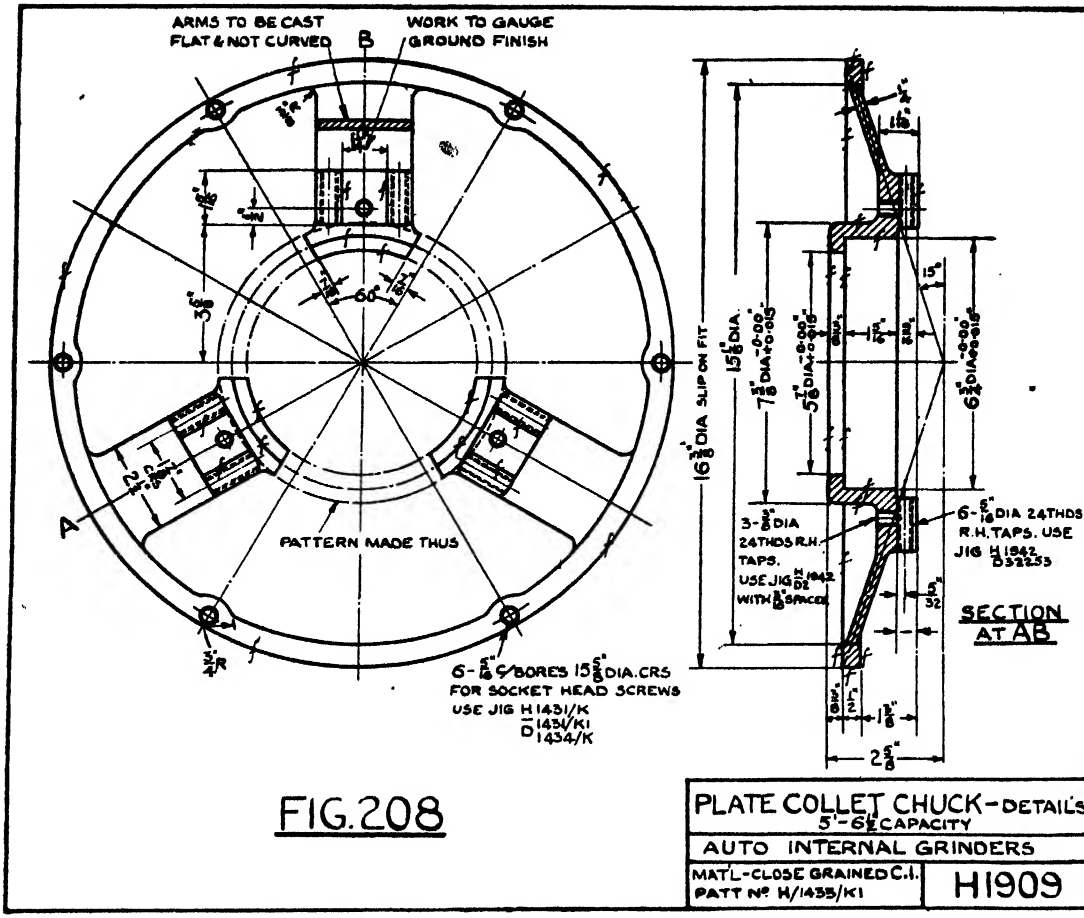
(1) Plot the locus of a point on the circumference of a circle $2\frac{5}{8}$ in. diameter which rolls on the inside of a circle $4\frac{7}{8}$ in. diameter.

(2) A circle 3 in. diameter is inside a circle $4\frac{1}{2}$ in. diameter and touches it at one point. The inner circle is fixed. Plot the locus of a point on the large circle when it rolls on the smaller circle.

(3) A circle $2\frac{1}{4}$ in. diameter rolls along a fixed line. Plot the locus of points: (*a*) 1 in. from the centre, (*b*) $1\frac{1}{2}$ in. from the centre when the circle makes $1\frac{1}{2}$ revolutions.

(4) Describe an involute using a $2\frac{1}{4}$ in. base circle. Draw a line tangential to the base circle to cut the involute, *i.e.*, one of the positions of the line rolling on the circle. Draw a normal to this line at the point of contact with involute (this is a tangent to the involute). Repeat for other points.

(5) A straight link ABC is $2\frac{1}{2}$ in. long and moves with point A in guides from P to Q and Q to R while C moves in guides from M to N and back to M. Plot the locus of the point B, 1 in. from C when (i) guides are perpendicular, (ii) guides are inclined at 60°.



(*Fig.* 208 *by permission of Messrs. The Churchill Machine Tool Co. Ltd.*)

(6) In a crank mechanism (fig. 31, page 21) OB is 1 ft. long and rod AB 4 ft. 3 in. long, but A moves in guides 6 in. above the axis O of crankshaft. Plot the locus of a point C on AB or AB produced when BC is (i) 1 ft. 3 in., (ii) 5 ft.

(7) Two cranks AB, CD are connected by a link BC (fig. 211*a*). The end C rotates in a complete circle while B oscillates on an arc about A. Plot locus of the middle point P of the link BC, AB = 2 ft. $4\frac{1}{2}$ in.; CD = 1 ft. 6 in.

(8) OA oscillates about O and PB oscillates about P (fig. 211*b*). Plot locus of point S and of point T for the complete movement.

(9) In fig. 211*c* cranks CA, DB oscillate about fixed centres C and D. CA = 5 ft. DB = 3 ft. AB = 2 ft., and when CA and DB are horizontal AB is vertical. Produce BA to P so that AP = BQ. Plot locus of P.

EXERCISE XIX

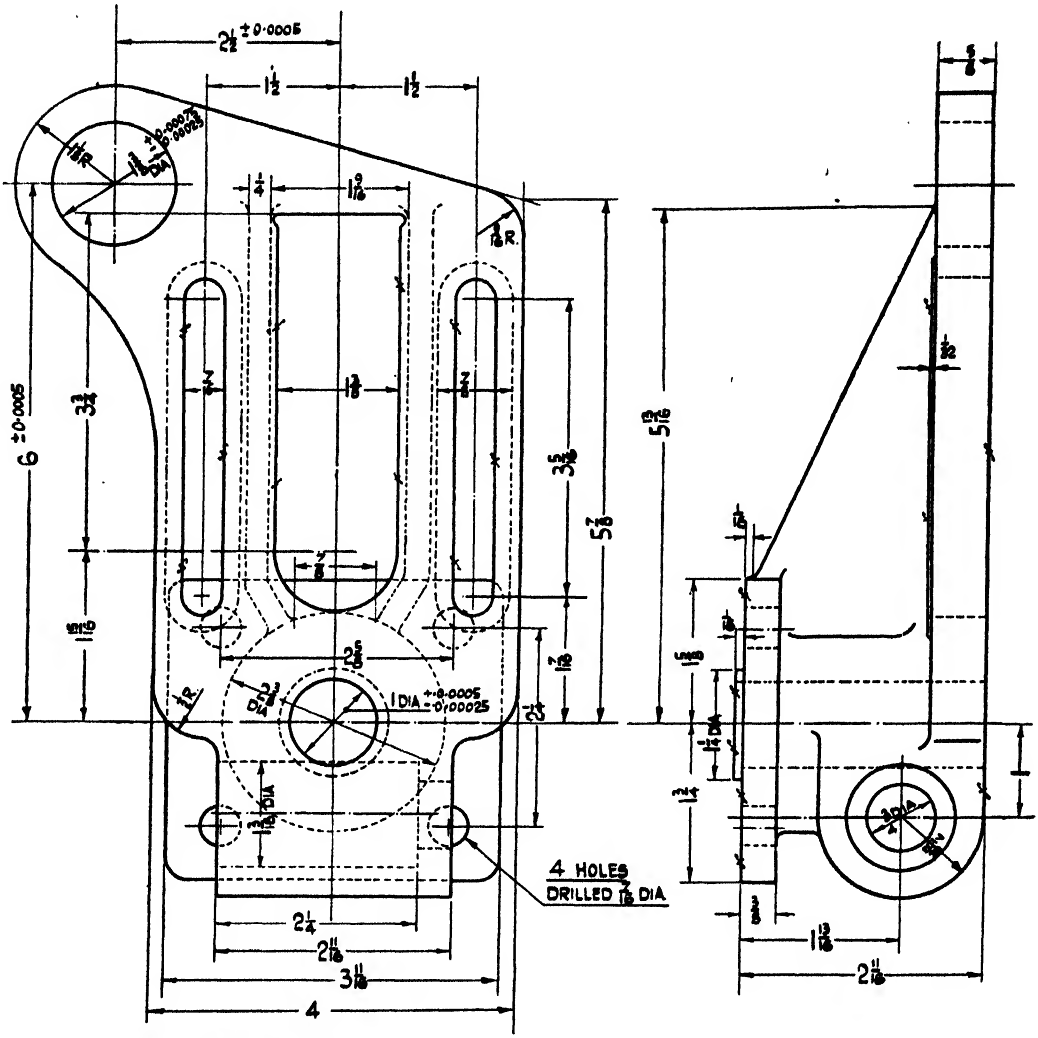
(1) Make isometric drawings of the following details using a full-size natural scale.
   (i) Tool slide, fig. 212*a*.
   (ii) Bearing brass, fig. 212*b*.
   (iii) Angle bracket, fig. 212*c*.
   (iv) Counterbalance weight, fig. 212*d*.
   (v) Vee holder of fig. 210.

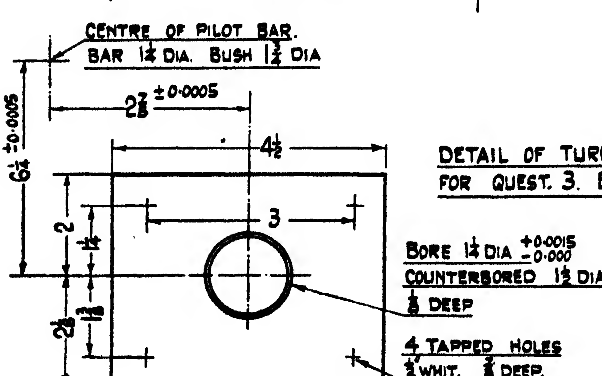
(2) Draw pictorial views of the following using an isometric scale:
   (*a*) Prism, fig. 47*d*, page 33.
   (*b*) Cylinder as cut in question 14, Example VI, page 34.
   (*c*) Clutch collar, fig. 54*c*, page 39.

(3) A cam is made by machining a disc with bosses on each side (fig. 213*a*). Show the cam in isometric using half natural scale.

(4) Make oblique projections of:
   (*a*) A 3 in. length of the extruded section, fig. 23*h*, page 15.
   (*b*) Bearing brass of question 1 above.

(5) A Vee block is shown in fig. 213*b*. Make a pictorial representation using (*a*) isometric, (*b*) oblique projection.





DETAIL OF TURRET FACE FOR QUEST. 3. Ex XVII.

KNEE TOOLHOLDER FOR CAPSTAN LATHE.

MAT'L CAST IRON.

FIG. 209.

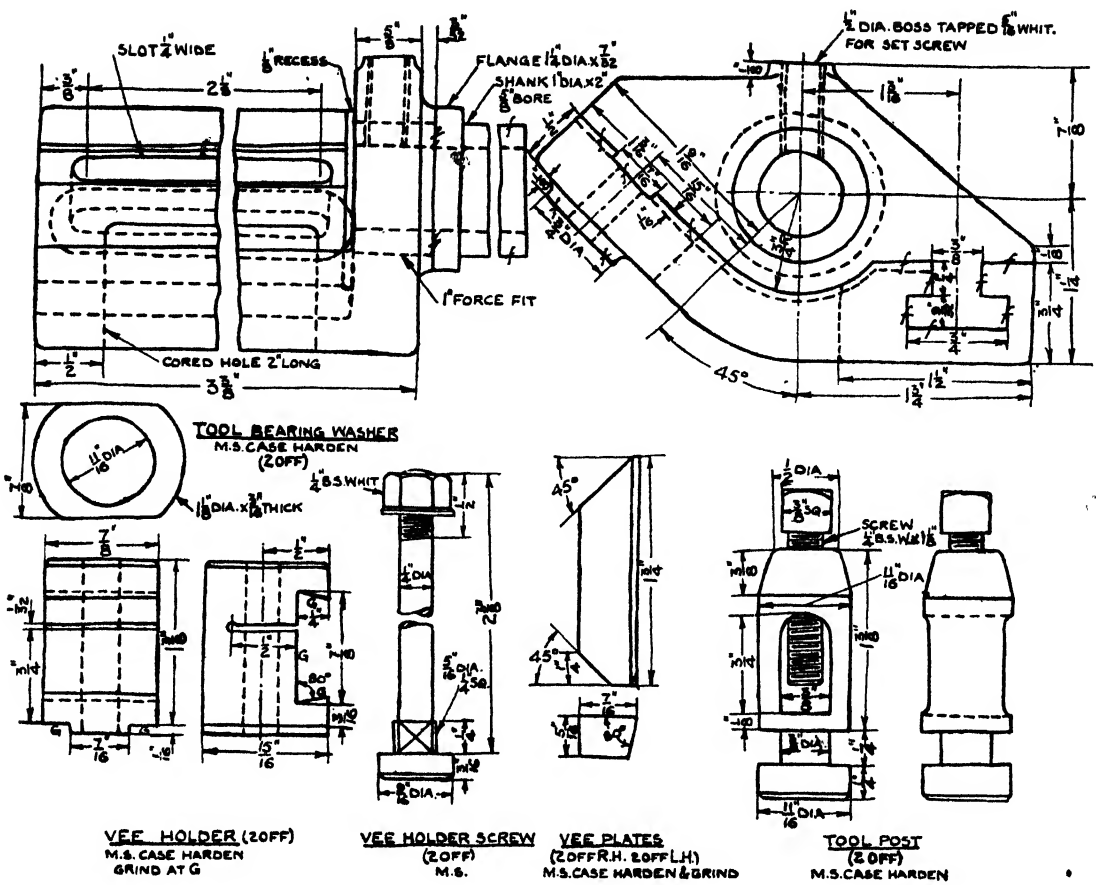


FIG. 210.

EXERCISE XX

(1) A disc 1⅜ in. diameter, ½ in. thick, has a segment removed by a slice as shown in fig. 214*a*. Copy the plan given and project the two elevations.

(2) The composite figure prism and pyramid shown in fig. 214*b* is cut by the plane indicated by the chain line. Draw three views of the block cut by the plane.

(3) The block, fig. 214*c*, is laid with face *aa*, *bb* on the HP and edge *aa*, at 60° to the VP. Draw three views of block in this position.

(4) A ring having a hexagonal hole has a flat surface as shown, fig. 214*d*. Draw plan and project the front elevation.

(5) A hexagonal prism having a rectangular hole is cut as shown, fig. 214*e*. Draw the three complete views.

(6) Draw three views of the uncut prism, question 5, when one rectangular face is in the HP and the hexagonal faces at 30° to VP.

(7) A square pyramid has 1¼ in. side and 2½ in. height. Draw three views of the pyramid when it lies with a triangular face on the HP and one edge of its base at 60° to the VP.

(8) The pyramid of question 7 is cut by a plane inclined at 30° to the HP and passing through a point on its axis ¾ in. from the apex. Draw the three views of the pyramid as cut by this plane, and project an auxiliary elevation looking on the face cut by the plane.

(9) Project an auxiliary plan of the ring in question 4 to give the true shape of the face cut by the plane.

(10) Project an auxiliary plan of the prism, question 5, on a plane parallel to the face sloping at 45°.

(11) A cone 1½ in. diameter base and 2¼ in. perpendicular height is resting with its curved surface on the HP and the line of contact with the HP is parallel to the VP. Draw plan and two elevations of the cone.

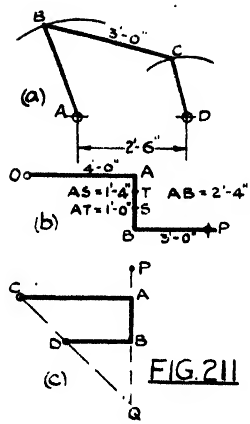
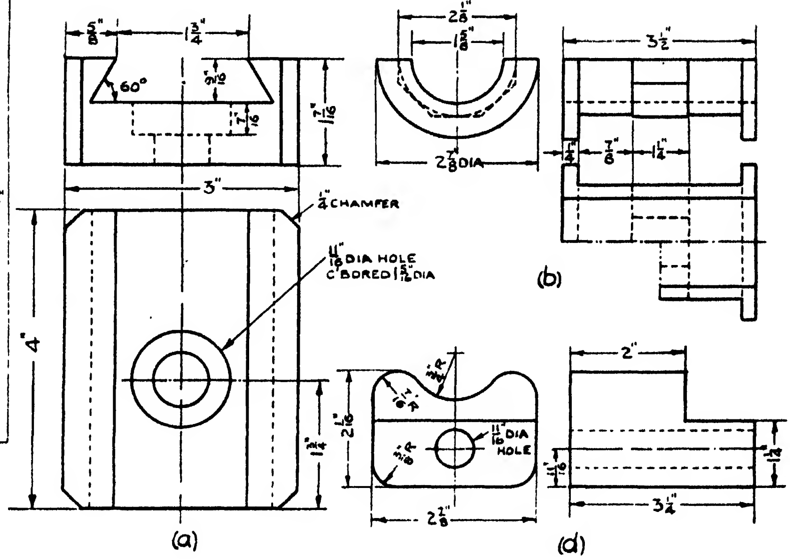


FIG. 211



(a) (b) (d)

FIG. 212

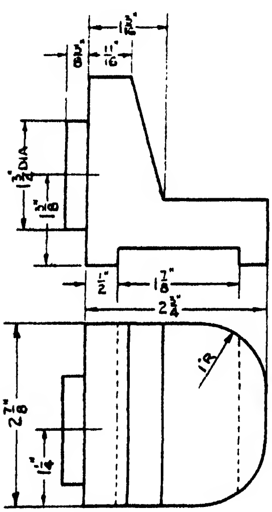
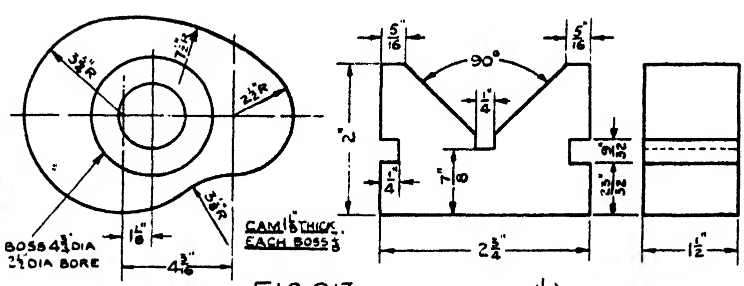
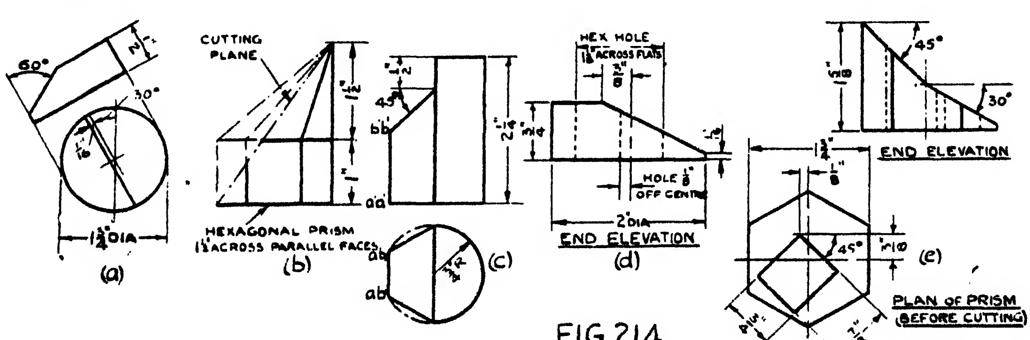


FIG. 212 (c)



(a) FIG. 213 (b)



(a) (b) (c) (d) (e)

FIG. 214

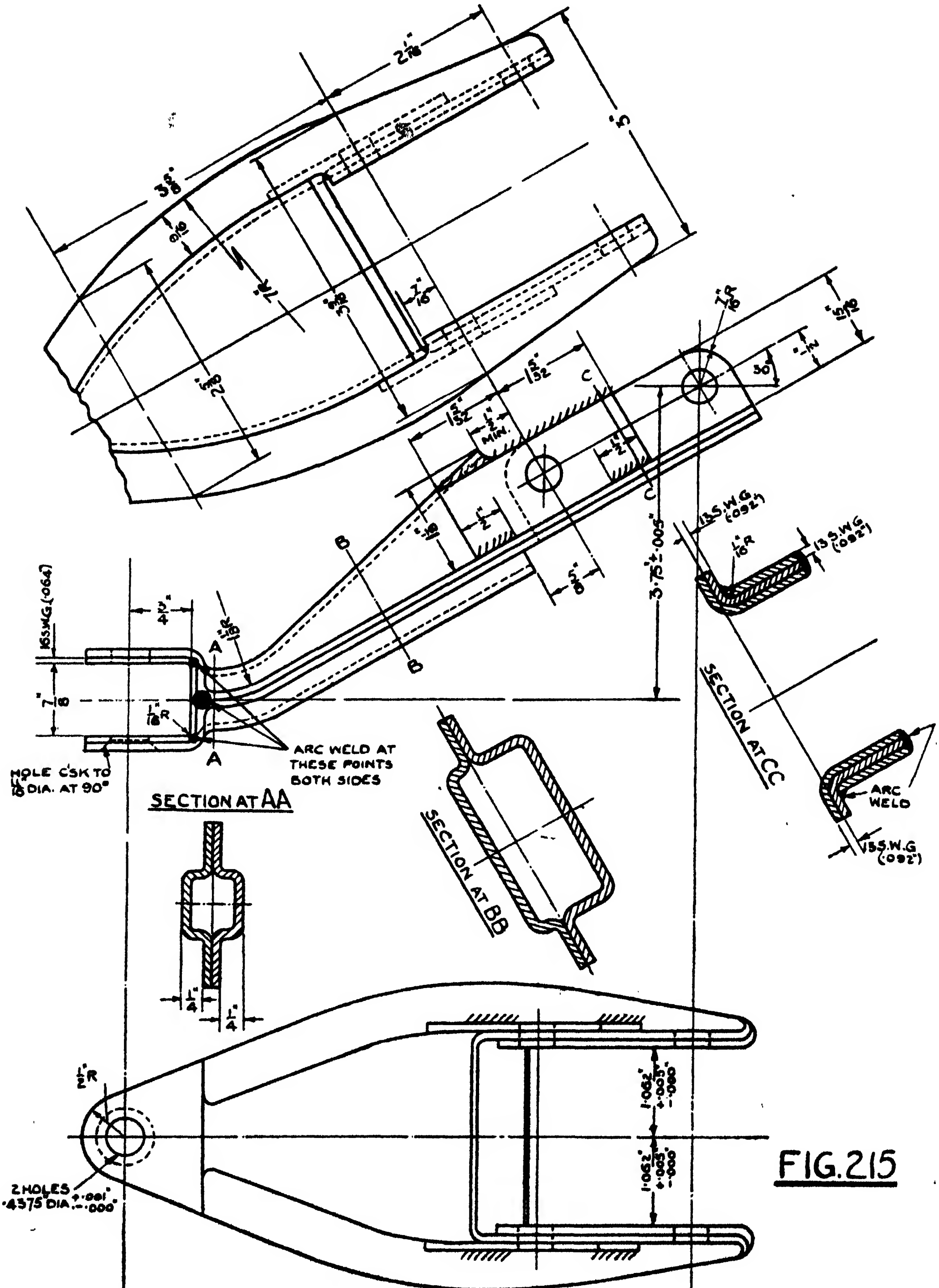


FIG. 215

(*Fig.* 215 *by permission of Messrs. Morris Motors Ltd.*)

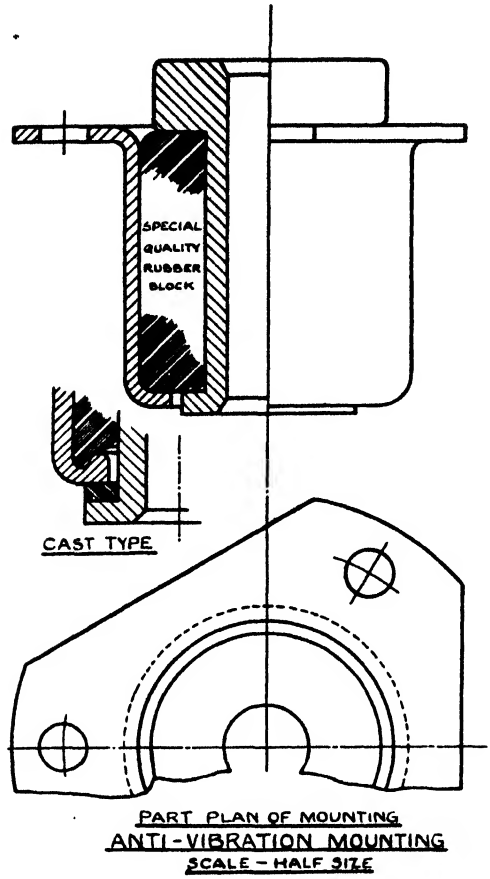


FIG. 216

(*Fig. 216 by permission of Messrs. Silentbloc Ltd.*)

(12) The cone of question 11 is cut by a vertical plane inclined at 45° to the VP and passing through the mid point of the axis of the cone. Draw three views of the cone as cut by the plane.

EXERCISE XXI

(1) Describe with sketches how the following components would be cast:
 (*a*) Cast steel crank, fig. 178, page 140.
 (*b*) Bracket, fig. 91*b*, page 74.
 (*c*) Piston, fig. 191*a*, page 149.

(2) Show by sketches where you would expect the flash on the following drop forgings:
 (*a*) Lever, fig. 154, page 122.
 (*b*) Flange, fig. 124*c*, page 98.
 (*c*) Rocker arm, fig. 186, page 146.
 (*d*) Cover, fig. 54*e*, page 39.

(3) A fabricated bracket is shown in fig. 215. Draw the four separate pressings (one, the 13-gauge stiffener, used in duplicate) of which it is constructed, in full detail.

(4) An anti-vibration mounting for a rail car generator, fig. 216, consists of a pressed steel container with a hard rubber insulating bush. Detail the pressed container. What type of tool would you suggest for its production?

(5) Redesign the container as a thin casting. Call for a pattern number to be cast, showing where it must be placed.

(6) Fig. 217 shows a fabricated magnet frame. Make a working drawing of a frame of similar construction of $10\frac{1}{2}$ in. bore, $6\frac{1}{4}$ in. long, with fixing centres, $10\frac{7}{8}$ in. × $8\frac{3}{8}$ in.

(7) Fig. 218 shows a clutch bracket for a large press. The casting is to be replaced by a fabricated bracket as shown. Detail (i) the attachment flange which is of steel 13 in. × $12\frac{1}{2}$ in. × 1 in.; (ii) vertical support flange of steel 5 in. × 12 in. × $\frac{3}{4}$ in.; (iii) horizontal support flange $5\frac{1}{2}$ in. × 10 in. × $\frac{3}{4}$ in.

(8) Make an assembly of the bracket, question 7, if main frame is of $\frac{5}{16}$ in. plate.

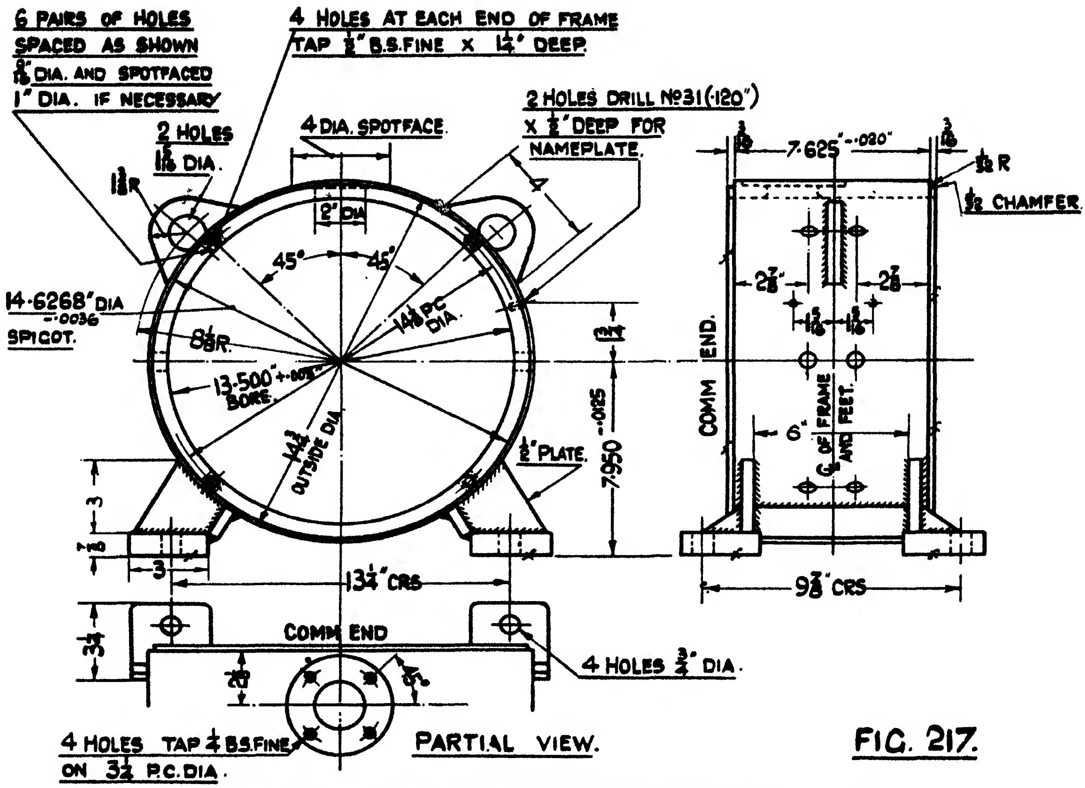


FIG. 217.

(*Fig. 217 by permission of Messrs. The British Thomson-Houston Co. Ltd.*)

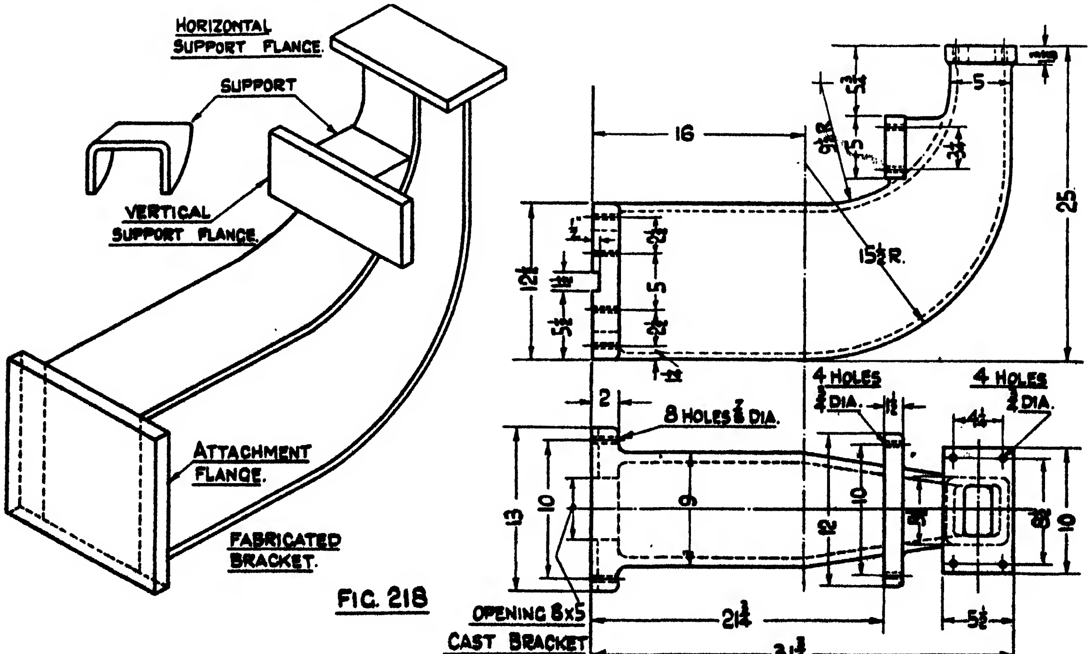


FIG. 218

(*Fig. 218 by permission of Messrs. Lincoln Electric Co. Ltd.*)

BRIEF NOTES ON MATERIALS

IRON

(1) **Cast.** Brittle, strong in compression, easily machined. Useful for brackets, bearing bases. May be strengthened by alloying elements.

(2) **Wrought.** Almost pure iron—tough and malleable, used for furnace bars, chains, pipes—is easily welded.

(3) **Malleable.** Prepared from hard cast iron (white iron). Gives tougher, malleable castings; used for pipe fittings, levers, etc.

STEEL

(1) **Mild Steel.** Steel having a very small percentage of carbon (0·1% to 0·5%), with no special alloying metal. It is easily machined, forged, cast or rolled. It may be given a hard skin, leaving a soft tough core by carburising.

(2) **Nickel Steel.** One of the most important alloy steels, used as bar or forging for components where great strength and toughness is required. The steel has from 1% to 5% nickel. Suitable heat treatments will give great toughness, strength or hardness. Variations in the properties are obtained by adding other elements such as chromium, molybdenum, etc.

(3) **Cast Steel.** A hard strong steel, used for tools and instruments. It has from 1% to 1·5% carbon, and may be hardened and tempered.

(4) **Free Cutting Steel.** A steel having a very small percentage of an alloying element, usually sulphur or lead, added expressly to improve the machinability. It should only be used for components which are not subject to great stress.

(5) **High Speed Steel.** A steel which, with suitable heat treatment, retains its hardness at high temperatures, particularly when used as a tool cutting at high speed. The properties are given by the inclusion of small percentages of tungsten, molybdenum, etc.

(6) **Bright Drawn Steel.** Steel drawn through a die to the required shape, but in the finishing stages, after pickling, the steel is drawn to accurate sizes whilst cold, so that no oxide skin is formed.

Cold Rolled Sheet. Steel sheet rolled after pickling whilst cold to give bright, accurate-sized sheet.

NON-FERROUS METALS

Copper. Used for piping (heat conducting) and as an electrical conductor. Otherwise chiefly with alloying elements.

Brass. Copper and zinc — approximately 60% to 70% copper according to the required properties—may be cast, forged, rolled, drawn or extruded.

Bronze. Copper and tin. Usually used with other alloying elements, such as manganese or phosphorus, to give hard, tough castings or bar.

Gunmetal. Copper, tin and zinc. Tough strong castings.

Aluminium. Very soft, rarely used without alloys.

Duralumin. Aluminium and copper. Very strong and light, may be forged, rolled or cast.

Aluminium alloys with silicon, manganese, bronze, etc., to produce a wide range of strong, light metals for castings, forging, rolling, extruding.

HEAT TREATMENT

Hardening. By heating to a given temperature, then cooling rapidly, either by plunging into oil or water, or by air blast, the structure of the carbides in steel is altered, and this increases the hardness. High carbon, nickel and various alloy steels may be hardened in this way.

Tempering. After hardening, to reduce the brittleness, certain steels may be reheated to a temperature lower than that in the hardening process, then cooled rapidly from this lower temperature.

Carburising. The formation of a high carbon skin on a low carbon material.

Prolonged heating of the component when completely surrounded by a carbonaceous material will allow the carbon to penetrate into the steel. Mild steel is often carburised. The harder carbon steel skin may then be rendered extremely hard by case hardening.

Case Hardening. The process of hardening a carburised component by heating and quenching in oil or water.

Cyanide Hardening. A skin hardening process using a molten salt, such as sodium or potassium cyanide, as the carbon-rich material. More delicate parts may be treated in the liquid with less risk of distortion.

Nitriding. The process of forming an extremely hard skin up to about 0·01 in. deep on steel, leaving a soft, tough core, by heating in ammonia gas which gives up nitrogen to react upon the aluminium included in the special nitriding steel.

Annealing. Prolonged heating at a high specified temperature, then very slowly cooling in the furnace. The process relieves the steel of internal stress induced by casting or mechanical working (*e.g.*, see page 116) and leaves the material soft and machinable.

Normalising. Prolonged heating, as in annealing, but cooling in still air. The purpose is also to relieve internal stresses, but not to soften. Normalising aims at a refinement of the steel structure to improve the properties of mechanical strength.

STANDARD TABLES

TABLE I

Small Snap Head Rivets

Extract from B.S. Spec. No. 641

D	A	B	R
$\frac{1}{16}$	0·109	0·047	0·055
$\frac{1}{8}$	0·219	0·094	0·111
$\frac{3}{16}$	0·322	0·141	0·166
$\frac{1}{4}$	0·438	0·188	0·221
$\frac{5}{16}$	0·547	0·234	0·277
$\frac{3}{8}$	0·656	0·281	0·332

A—$1\frac{3}{4}$D. B—0·75D. R—0·885D.

Dimensions A and B refer to snap head rivets only. For other standard proportions see figure below.

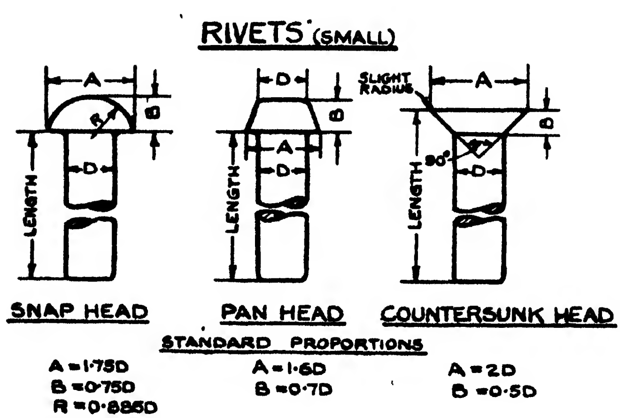


TABLE II

B.S. WHIT. THREAD BASIC DIMENSIONS

Extract from B.S. Spec. No. 84 : 1940

Size	Threads per Inch	Depth of Thread	Major Diameter	Effective Diameter	Minor Diameter
$\frac{1}{4}$	20	0·0320	0·2500	0·2180	0·1860
$\frac{5}{16}$	18	0·0356	0·3125	0·2769	0·2413
$\frac{3}{8}$	16	0·0400	0·3750	0·3350	0·2950
$\frac{7}{16}$	14	0·0457	0·4375	0·3918	0·3461
$\frac{1}{2}$	12	0·0534	0·5000	0·4466	0·3932
$\frac{5}{8}$	11	0·0582	0·6250	0·5688	0·5086
$\frac{3}{4}$	10	0·0640	0·7500	0·6860	0·6220
$\frac{7}{8}$	9	0·0711	0·8750	0·8039	0·7328
1	8	0·0800	1·0000	0·9200	0·8400
$1\frac{1}{8}$	7	0·0915	1·1250	1·0335	0·9420
$1\frac{1}{4}$	7	0·0915	1·2500	1·1585	1·0670
$1\frac{1}{2}$	6	0·1067	1·5000	1·3933	1·2866
$1\frac{3}{4}$	5	0·1281	1·7500	1·6219	1·4938
2	4·5	0·1423	2·0000	1·8577	1·7154

TABLE III

B.S. FINE THREAD BASIC DIMENSIONS

Extract from B.S. Spec. No. 84 : 1940

Size	Threads per Inch	Depth of Thread	Major Diameter	Effective Diameter	Minor Diameter
$\frac{1}{4}$	26	0·0246	0·2500	0·2254	0·2008
$\frac{5}{16}$	22	0·0291	0·3125	0·2834	0·2543
$\frac{3}{8}$	20	0·0320	0·3750	0·3430	0·3110
$\frac{7}{16}$	18	0·0356	0·4375	0·4019	0·3663
$\frac{1}{2}$	16	0·0400	0·5000	0·4600	0·4200
$\frac{5}{8}$	14	0·0457	0·6250	0·5793	0·5336
$\frac{3}{4}$	12	0·0534	0·7500	0·6966	0·6432
$\frac{7}{8}$	11	0·0582	0·8750	0·8168	0·7586
1	10	0·0640	1·0000	0·9360	0·8720

(TABLE III *continued on opposite page*)

TABLE III (*continued*)

Size	Threads per Inch	Depth of Thread	Major Diameter	Effective Diameter	Minor Diameter
1⅛	9	0·0711	1·125	1·0539	0·9828
1¼	9	0·0711	1·250	1·1789	1·1078
1½	8	0·0800	1·500	1·4200	1·3400
1¾	7	0·0915	1·750	1·6585	1·5670
2	7	0·0915	2·000	1·9085	1·8170

TABLE IV

B.S. Parallel Pipe Thread Basic Dimensions when used for General Engineering Purposes

Extract from B.S. Spec. No. 84 : 1940

B.S.P. Size	Number of Threads per Inch	Depth of Thread	Major Diameter	Effective Diameter	Minor
⅛	28	0·0229	0·3830	0·3601	0·3372
¼	19	0·0337	0·5180	0·4843	0·4506
⅜	19	0·0337	0·6560	0·6223	0·5886
½	14	0·0457	0·8250	0·7793	0·7336
⅝	14	0·0457	0·9020	0·8563	0·8106
¾	14	0·0457	1·0410	0·9953	0·9496
⅞	14	0·0457	1·1890	1·1433	1·0976
1	11	0·0582	1·3090	1·2508	1·1926
1¼	11	0·0582	1·6500	1·5918	1·5336
1½	11	0·0582	1·8820	1·8238	1·7656
1¾	11	0·0582	2·1160	2·0578	1·9996
2	11	0·0582	2·3470	2·2888	2·2306

3 + 2 7

TABLE V

British Association Thread

B.A. No.	Full Diameter of Thread		Minor Diameter	Head Sizes	
				W	A
	Millimetres	Inch	Inch	Inch	Inch
0	6·0	0·236	0·189	0·413	0·177
1	5·3	0·209	0·166	0·365	0·156
2	4·7	0·185	0·147	0·319	0·139
3	4·1	0·161	0·127	0·285	0·121
4	3·6	0·142	0·111	0·252	0·106
5	3·2	0·126	0·098	0·221	0·094
6	2·8	0·110	0·085	0·194	0·083
7	2·5	0·098	0·076	0·175	0·074
8	2·2	0·087	0·066	0·158	0·065
9	1·9	0·075	0·056	0·127	0·056
10	1·7	0·067	0·05	0·111	0·050
11	1·5	0·059	0·044	0·111	0·044
12	1·3	0·051	0·038	0·096	0·038

W—Diameter of head for all classes except connection head, and width across flats of hexagonal head 1·75D.

A—Depth of cheese and hexagonal head.

For further particulars see B.S. Spec. No. 57.

TABLE VI

B.S. Whit. Bolt Head and Nut (Large Hexagon)

Extract from B.S. Spec. No. 190

Diameter	Number of Threads per Inch	Width of Flats. Maximum	Approximate Distance across Corners	Thickness of Head. Maximum	Thickness of Nut. Maximum	Thickness of Locknut. Maximum
$\frac{1}{4}$	20	0·525	0·61	0·22	0·250	0·166
$\frac{5}{16}$	18	0·600	0·69	0·27	0·312	0·208
$\frac{3}{8}$	16	0·710	0·82	0·33	0·375	0·250
$\frac{7}{16}$	14	0·820	0·95	0·38	0·437	0·291
$\frac{1}{2}$	12	0·920	1·06	0·44	0·500	0·333
$\frac{5}{8}$	11	1·100	1·27	0·55	0·625	0·416
$\frac{3}{4}$	10	1·300	1·50	0·66	0·750	0·500
$\frac{7}{8}$	9	1·480	1·71	0·77	0·875	0·583
1	8	1·670	1·93	0·88	1·000	0·666

(TABLE VI *continued on opposite page*)

TABLE VI (*continued*)

Diameter	Number of Threads per Inch	Width of Flats. Maximum	Approximate Distance across Corners	Thickness of Head. Maximum	Thickness of Nut. Maximum	Thickness of Locknut. Maximum
$1\frac{1}{8}$	7	1·860	2·15	0·98	1·125	0·750
$1\frac{1}{4}$	7	2·050	2·37	1·09	1·250	0·833
$1\frac{1}{2}$	6	2·410	2·78	1·31	1·500	1·000
$1\frac{3}{4}$	5	2·760	3·19	1·53	1·750	1·166
2	4·5	3·150	3·64	1·75	2·000	1·333

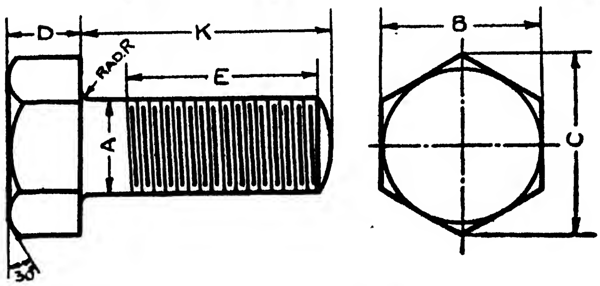


FIG. 1—HEXAGON HEADED BOLT

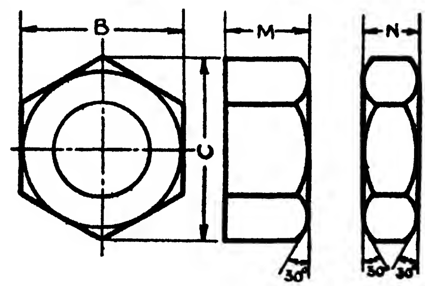


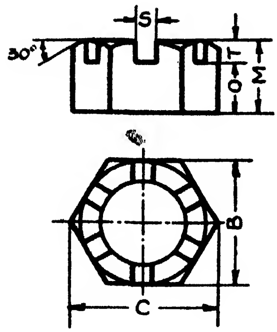
FIG. 2—HEXAGON NUT & LOCKNUT

TABLE VII

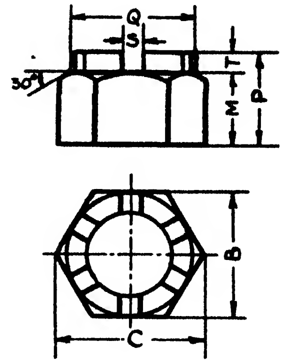
Dimensions of Bolts, Nuts and Locknuts

Extract from B.S. Spec. No. 1083 : 1942 (Superseding B.S. 191 and 193)

Nominal Size	Number of Threads per Inch.		Bolts, Nuts, Set Screws.		Bolts, Set Screws.		Nuts. Thickness. Maximum	Locknuts. Thickness. Maximum
	B.S.W.	B.S.F.	Width across Flats. Maximum	Approximate Width across Corners	Thickness of Head. Maximum	Radius under Head		
A			B	C	D	R	M	N
$\frac{1}{4}$	20	26	0·445	0·51	0·19	$\frac{1}{32}$	0·200	0·133
$\frac{5}{16}$	18	22	0·525	0·61	0·22	$\frac{1}{32}$	0·250	0·166
$\frac{3}{8}$	16	20	0·600	0·69	0·27	$\frac{1}{32}$	0·312	0·208
$\frac{7}{16}$	14	18	0·710	0·82	0·33	$\frac{1}{32}$	0·375	0·250
$\frac{1}{2}$	12	16	0·820	0·95	0·38	$\frac{1}{32}$	0·437	0·291
$\frac{5}{8}$	11	14	1·010	1·17	0·49	$\frac{1}{32}$	0·562	0·375
$\frac{3}{4}$	10	12	1·200	1·39	0·60	$\frac{1}{32}$	0·687	0·458
$\frac{7}{8}$	9	11	1·300	1·50	0·66	$\frac{1}{32}$	0·750	0·500
1	8	10	1·480	1·71	0·77	$\frac{1}{32}$	0·875	0·583
$1\frac{1}{8}$	7	9	1·670	1·93	0·88	$\frac{3}{64}$	1·000	0·666
$1\frac{1}{4}$	7	9	1·860	2·15	0·98	$\frac{3}{64}$	1·125	0·750
$1\frac{1}{2}$	6	8	2·220	2·56	1·20	$\frac{3}{64}$	1·375	0·916
$1\frac{3}{4}$	5	7	2·580	2·98	1·42	$\frac{3}{64}$	1·625	1·083
2	4·5	7	2·760	3·19	1·53	$\frac{3}{64}$	1·750	1·166



SLOTTED NUT
FIG. 3



CASTLE NUT
FIG. 4

TABLE VIII

Dimensions of Slotted Nuts and Castle Nuts

Extract from B.S. Spec. No. 1083 : 1942 (Superseding B.S. 191 and 193)

Nominal Size	Slotted Nuts.		Castle Nuts.				Slotted and Castle Nut. Approximate Dimensions of Slot.	
	Thickness	Face of Nut to Bottom of Slot	Thickness of Hexagon and from Face of Nut to Bottom of Slot	Total Thickness	Castellated Portion. Diameter	Approximate Radius	Width	Depth
A	M	O	M	P	Q	R	S	T
$\frac{1}{4}$	0·260	0·170	0·200	0·290	0·430	0·04	0·090	0·090
$\frac{5}{16}$	0·280	0·190	0·250	0·340	0·510	0·05	0·090	0·090
$\frac{3}{8}$	0·312	0·222	0·312	0·402	0·585	0·05	0·090	0·090
$\frac{7}{16}$	0·375	0·235	0·375	0·515	0·695	0·06	0·125	0·140
$\frac{1}{2}$	0·437	0·297	0·437	0·577	0·805	0·06	0·125	0·140
$\frac{5}{8}$	0·562	0·375	0·562	0·749	0·995	0·07	0·165	0·187
$\frac{3}{4}$	0·687	0·453	0·687	0·921	1·185	0·08	0·208	0·234
$\frac{7}{8}$	0·750	0·516	0·750	0·984	1·285	0·08	0·208	0·234
1	0·875	0·595	0·875	1·155	1·465	0·09	0·250	0·280
$1\frac{1}{8}$	1·000	0·720	1·000	1·280	1·655	0·09	0·250	0·280
$1\frac{1}{4}$	1·125	0·797	1·125	1·453	1·845	0·10	0·290	0·328
$1\frac{1}{2}$	1·375	1·047	1·375	1·703	2·200	0·12	0·290	0·328
$1\frac{3}{4}$	1·625	1·250	1·625	2·000	2·555	0·14	0·333	0·375
2	1·750	1·282	1·750	2·218	2·735	0·14	0·416	0·468

R = Radius on castellated portion of Castle Nut.

TABLE IX

Rectangular Parallel Keys

Extract from B.S. Spec. No. 46

Shaft Diameter		Key		Length. Maximum
Over	Up to and including	Nominal Width	Nominal Thickness	
$\frac{3}{16}$	$\frac{1}{4}$	$\frac{3}{32}$	$\frac{3}{32}$	$\frac{3}{4}$
$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	1
$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{32}$	$\frac{5}{32}$	$1\frac{1}{4}$
$\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{16}$	$\frac{5}{32}$	$1\frac{1}{2}$
$\frac{3}{4}$	1	$\frac{1}{4}$	$\frac{3}{16}$	2
1	$1\frac{1}{4}$	$\frac{5}{16}$	$\frac{7}{32}$	$2\frac{1}{2}$
$1\frac{1}{4}$	$1\frac{1}{2}$	3 [illegible]	$\frac{1}{4}$	3
$1\frac{1}{2}$	$1\frac{3}{4}$	$\frac{7}{16}$	$\frac{9}{32}$	$3\frac{1}{2}$
$1\frac{3}{4}$	2	$\frac{1}{2}$	$\frac{11}{32}$	4
2	$2\frac{1}{4}$	$\frac{9}{16}$	$\frac{3}{8}$	5
$2\frac{1}{4}$	$2\frac{1}{2}$	$\frac{5}{8}$	$\frac{13}{32}$	5
$2\frac{1}{2}$	$2\frac{3}{4}$	$\frac{11}{16}$	$\frac{15}{32}$	6
$2\frac{3}{4}$	3	$\frac{3}{4}$	$\frac{1}{2}$	6
3	$3\frac{1}{2}$	$\frac{7}{8}$	$\frac{5}{8}$	7
$3\frac{1}{2}$	4	1	$\frac{11}{16}$	8
4	$4\frac{1}{2}$	$1\frac{1}{8}$	$\frac{3}{4}$	10
$4\frac{1}{2}$	5	$1\frac{1}{4}$	$\frac{13}{16}$	10
5	$5\frac{1}{2}$	$1\frac{3}{8}$	$\frac{15}{16}$	12
$5\frac{1}{2}$	6	$1\frac{1}{2}$	1	12
6	$6\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{1}{16}$	14

TABLE X

Proportions of Cheese, Round and Countersunk Head Screws

(For further details see B.S. Spec. No. 450)

Head	Diameter of Head	Depth of Head
Cheese	$1\frac{1}{2}$D	0·8D
Round	$1\frac{3}{4}$D	0·8D
Countersunk	$1\frac{3}{4}$D	$\frac{3}{8}$D countersunk + 0·01 in. to 0·02 in. cylindrical portion

D = Screw thread diameter.

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